MICHIGAN FOREST HEALTH REPORT

1991-1993

Michigan Cooperative Forest Pest Management Program

DNR

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Michigan Forest Health Report

1991-1993

Carolyn J. Randall

Editor

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PREFACE

Overview of the Michigan Cooperative Forest Pest Management Program

The Michigan Cooperative Forest Pest Management Program is firmly dedicated to helping fulfill forest management objectives by providing forest land managers with practical pest management information to improve decision making. In existence since the mid-1970's, the program brings together expertise from seven cooperating organizations.

Member institutions of the Michigan Cooperative Forest Pest Management Program include:

Michigan Department of Natural Resources

Michigan Department of Agriculture

Michigan State University

Michigan Technological University

University of Michigan

USDA Forest Service NCFES

USDA Forest Service NE Area State and Private Forestry

Directors of the Forest Pest Management Program are:

Robert A. Haack, USDA Forest Service, and John F. Witter, University of Michigan, Co-Directors of Research and Development

Deborah A. McCullough, Michigan State University, Co-Director of Technology Transfer

Frank J. Sapio, Department of Natural Resources, Co-Director of Field Applications

Purpose of the *Michigan Forest Health Report: 1991-93*:

The *Michigan Forest Health Report: 1991-93* is the Forest Pest Management Program's ninth cooperative report. It is one way that the Cooperative Program disseminates pest management and resource condition information to forest land managers. This report primarily summarizes forest health information from the 1991, 1992, and 1993 field seasons but also covers salient topics from previous years when we did not publish a report. Contributors to the report include forest pest specialists and forest health specialists from universities, government agencies, and extension. The time that they take to inform the Michigan forest land manager about the results from research and development projects helps all of us keep abreast of Michigan's forest health and pest management issues and concepts.

Where to Obtain a Copy of the 1991-93 Forest Health Report:

Copies of the *Michigan Forest Health Report: 1991-93* are available from the Michigan Department of Natural Resources, Forest Management Division, 8th Floor Mason Bldg, Box 30452, Lansing, MI 48909-7952, c/o Frank Sapio.

CONTRIBUTORS

(in alphabetical order)

Botti, Bill
Michigan Department of Natural Resources

Burton, Andrew
Michigan Technological University

Chilcote, Charley
Michigan State University

Haack, Robert
USDA Forest Service

Hallett, Rob
Clare County Gypsy Moth Program

Hart, John
Michigan State University

Heyd, Robert
Michigan Department of Natural Resources

Jurgenson, Marty
Michigan Technological University

Karnosky, David
Michigan Technological University

Lawrence, Robert
USDA Forest Service

Leichty, Hal
Michigan Technological University

Leutscher, Bruce
University of Michigan

MacDonald, Neil
Grand Valley State University

McCullough, Deborah
Michigan State University

Mech, Roger
Michigan Department of Natural Resources

Montgomery, Michael
USDA Forest Service

Mroz, Glenn
Michigan Technological University

Pregitzer, Kurt
Michigan Technological University

Randall, Carolyn
Michigan State University

Reed, David
Michigan Technological University

Sapio, Frank
Michigan Department of Natural Resources

Stoyenoff, Jennifer
University of Michigan

Weinrich, Jerry
Michigan Department of Natural Resources

Witter, John
University of Michigan

Zak, Don
University of Michigan

TABLE OF CONTENTS

PREFACE i

CONTRIBUTORS iii

CONTENTS iv

GLOSSARY OF TERMS vi

FOREWORD ix

FOREST HEALTH CONDITIONS: UPPER PENINSULA

I. PEST REPORTS

OPENING SUMMARY: REGION I 1

PEST REPORTS: UPPER PENINSULA HARDWOODS 1

Forest Tent Caterpillar 1

Oak Mortality:Two-Lined Chestnut Borer 3

Oak Wilt in Menominee County 4

Maple Decline 4

Willow Blight 4

PEST REPORTS: UPPER PENINSULA CONIFERS 5

Redheaded Pine Sawfly 5

Scleroderris Canker of Northern Conifers 5

White Grub Damage on Tree Seedlings 5

Pine Engraver Beetles 6

Salt Injury 6

Yellow-Headed Spruce Sawfly 6

MINOR PEST PROBLEMS: REGION I 7

II. PROJECT REPORTS

WHITE BIRCH RESOURCE EVALUATION 8

THE GYPSY MOTH 12

SLOW-THE-SPREAD: A PILOT TEST FOR MICHIGAN'S UPPER PENINSULA 13

JACK PINE BUDWORM 14

FOREST HEALTH CONDITIONS: NORTHERN LOWER PENINSULA

OPENING SUMMARY: REGION II 19

GYPSY MOTH 19

OAK MORTALITY 21

Introduction 21

Oak and Susceptibility to Decline 21

The History of Oak Decline in Michigan 22
The Status of Oak Decline in Michigan 22
A Problem: Oak Growing on Pine Sites 22
The Role of Secondary Pests 22
The Effect of Stress on Oak and Oak Regeneration 23
Dealing with Decline and Two-Lined Chestnut Borer 23
Sanitation 23
Salvage 23
Sitting Tight 23
Things to Remember 23
MINOR PEST PROBLEMS: REGION II 24
PLANTATION STOCKING AND SURVIVAL 25

GYPSY MOTH IN MICHIGAN

EFFECTS OF TREE SPECIES AND SITES ON SURVIVAL AND GROWTH OF THE GYPSY MOTH 31
THE EFFECTS OF VARIOUS DIET SEQUENCES ON GYPSY MOTH REARED UNDER FIELD CONDITIONS IN MICHIGAN 33
MICHIGAN GYPSY MOTH IMPACT MONITORING SYSTEM (MIMS) 33
RESEARCH ON THE IMPACT OF GYPSY MOTH ON ASPEN IN MICHIGAN 35
GYPCHECK--A FUTURE ALTERNATIVE 37

CLIMATE AND AIR POLLUTION

CLIMATIC AND POLLUTION INFLUENCES ON ECOSYSTEM PROCESSES IN NORTHERN HARDWOOD FORESTS 39
EFFECTS OF AN AIR POLLUTION GRADIENT ON NORTHERN HARDWOOD FORESTS IN THE NORTHERN GREAT LAKES REGION: FINAL REPORT 40

FOREST HEALTH CONDITIONS: SPECIAL PROJECTS

FOREST INVENTORY AND ANALYSIS: 1991-1992 DAMAGE CODE STANDARDIZATION PROJECT 45
DETERMINATION AND QUANTIFICATION OF SUGAR MAPLE DECLINE IN MICHIGAN 45
RESEARCH SUMMARIES: FOREST ENTOMOLOGY PROGRAM MICHIGAN STATE UNIVERSITY 47
Endangered Karner Blue Butterfly 47
Jack Pine Budworm 47
Native Forest Insect Biodiversity 47
Gypsy Moth Biological Control 48
Christmas Tree IPM 48
Gypsy Moth Education 48
LARGER PINE SHOOT BEETLE 49
YELLOWHEADED SPRUCE SAWFLY 50
THE KIRTLAND'S WARBLER IN 1993 50
REFORESTATION 53

GLOSSARY OF TERMS

The following is a list of terms from the fields of forestry and forest ecology that appear in various articles throughout this report.

For further definitions the reader is referred to *Terminology of Forest Science, Technology, Practice and Products,* 1983, published by the Society of American Foresters, and from which some of these definitions were derived.

B.t. -- *Bacillus thuringiensis*, a naturally occurring bacterium that affects certain caterpillars and is used as a biological control in suppression programs aimed at gypsy moth and some other insect pests.

Basal Area -- Tree cross-sectional areas as computed for **DBH** measurements. The basal area for an entire stand of trees is often expressed as square feet per acre or square meters per hectare.

Biomass -- The total quantity of living plants and/or organisms at a given time, usually expressed in weight per unit area.

Canker -- A depressed and/or discolored area on the stem or branches of a tree caused by invasion by a pathogenic organism(s) and death and decay of **host** tissues.

Canopy -- A closed layer of tree crown cover, usually referring to the uppermost layer.

Chain -- A unit of linear measurement traditionally used in forestry to measure horizontal distances. One chain is 66 feet long.

Clearcut -- A silvicultural cutting method in which the old crop is cleared over a considerable area at one time. Regeneration of the site results in an even-aged forest.

Clone -- an asexually derived organism that is genetically identical to the parent organism.

Codominant -- An expression of crown class which refers to trees with crowns in the upper forest canopy and receiving full light from above, but tend to have slightly smaller, moderately sized crowns as compared to trees in the **dominant** size class.

Cord -- A measurement of wood cut for fuel or pulpwood (128 cubic feet, as arranged in a pile 8 feet long, 4 feet high, and 4 feet wide).

Cordwood -- Wood stacked or sold in cords.

Crown -- The top part of the tree that includes the needles/leaves.

Crown Class -- Determined by the position and size of a tree's crown within the forest canopy, the four major crown classes are **dominant, codominant, intermediate** and **suppressed.**

DBH -- Diameter-at-breast height, the diameter of the tree as measured from 4.5 feet above the ground.

Decline -- The gradual failure in health of a tree, often (but not solely) associated with diseases of complex origin--i.e. diseases caused by more than one stress-inducing factor of both biotic and abiotic origin.

Dieback -- A symptom of tree decline in which branches appear to be dying from the tip back, often characterized by early fall coloration and leaf drop.

Dominant -- An expression of crown class which refers to trees with crowns in the upper forest canopy and receiving full light from above. They are larger than the average trees within a stand and have well-developed crowns.

Dry Deposition -- A form of nutrient input to the ecosystem that occurs as dry particulate fallout from the atmosphere.

Ecosystem -- A system made up of communities of plants, animals and microorganisms and their interrelated physical environments, and includes both the organic and inorganic aspects involved in the cyclic processes of life.

Flushing -- The time of vegetative bud burst and emergence of needles/leaves.

Flux -- A term which describes changes in nutrient inputs and outputs to the ecosystem.

Host -- any organism upon which another (parasitic) organism lives on, deriving nourishment and/or protection.

Intermediate -- An expression of crown class which refers to trees with crowns in the middle to upper canopy. They are shorter and have smaller crowns than the **dominant** and **codominant** size classes and receive little direct light from above.

Leaf Area Index (LAI) -- Leaf surface area per unit land area.

Litterfall -- Decomposable organic matter that falls to the ground as dead material; a form of nutrient input to the ecosystem.

Merchantable -- Refers to pulpwood or saw log sections that meet pulpwood or saw log specifications, respectively.

Mycorrhizae -- Fungi which form symbiotic associations with the root

cells of certain plants, thus functioning as root hairs and increasing absorption of nutrients.

Overstory -- The trees in a forest of more than one story that form the upper or uppermost canopy layer.

Phenology -- The study of naturally reoccurring phenomena and of their relation to climate and changes in season, i.e. development over time.

Pioneer -- A plant capable of invading bare sites (i.e. newly disturbed) and persisting there until supplanted by successor species.

Primary Pest -- The organism that initially stresses the tree, weakening it and predisposing it to attacks by **secondary pests.** It is often associated with **decline** diseases of complex origin.

Pulpwood -- Wood that is used in making paper.

Rotation Age -- The recommended age for harvesting of a mature stand of trees based on physiological and economic variables.

Salvage cutting -- The exploitation of trees that are dead, dying, or deteriorating before their timber becomes worthless.

Saw log -- A log meeting minimum standards of diameter, length, and freedom from defect. Saw logs are taken from sawtimber trees that are commercial species containing at least a 12-foot log or two noncontiguous saw logs 8 feet or longer.

Secondary Pest -- The organism(s) which is attracted to a tree that has been weakened by a **primary pest,** The primary and secondary pest(s) in combination with abiotic factors such as weather extremes and site conditions may lead to the eventual death of the tree. They are often associated with **decline** diseases of complex origin.

Shelterwood -- A silvicultural cutting method in which, in order to provide a source of seed and/or protection for regeneration, the old crop (the shelterwood) is removed in two or more successive shelterwood cuttings. An even-aged stand results.

Shade Intolerant -- Tree species that grow best under high light conditions and are thus adapted to colonizing open sites with little shade or crown cover.

Shade Tolerant -- Tree species that grow best under low light conditions and are thus able to outcompete shade-intolerant species on the shaded forest floor.

Silviculture -- the art and science of growing forests.

Site Index -- An expression of the quality of a forest site as determined by the average height of **dominant** and **codominant** trees of a representative species within the forest type. It is usually expressed as **site index (50)** or the height of trees within the stand at 50 years of age.

Stand -- A community of naturally or artificially established trees of any age sufficiently uniform in composition, constitution, age, spatial arrangement, or condition to be distinguishable from adjacent communities thereby forming a silvicultural management entity.

Stand Volume -- A measurement of the amount of timber at a silvicultural management site often expressed as **cords/acre.**

Succession -- The gradual supplanting of one plant community by another over time.

Suppressed -- An expression of crown class with refers to trees with crowns in the lower canopy and receiving little or no direct light from above.

Thinning -- An intermediate cut made in an immature stand primarily to maintain or accelerate diameter increment and also to improve the average form of the remaining trees.

Throughfall -- A form of nutrient input into the ecosystem that occurs from moisture dripping through the crown canopy.

Understory -- Trees and woody species growing under an **overstory**.

Wet Deposition -- A form of nutrient input into the ecosystem that occurs from particulate matter in the atmosphere that is dissolved in incident precipitation.

FOREWORD

To begin this report, I would first like to mention that Michigan's forests are in fairly good condition. Forest acreages have increased by over 6 percent since 1980. Growing stock has increased by 42 percent during the same time period. The greatest expansion of our inventory was concentrated in trees of larger diameter size classes. Local declines and mortality have not been uncommon, but it has to be understood that this is often the nature of the forest resource.

Change is a natural part of forest ecosystems. Forest decline is particularly noticeable in even-aged stands where overmature trees are dying at the same point in time and are eventually replaced by younger, more vigorously growing trees. Even in uneven-aged stands, certain plant communities are replaced by others in the natural process of succession. Because of this constant change, forest health is essentially a moving target. Dynamic ecological processes make it difficult to describe forest health at any given time. Confounding this issue is the fact that society puts values on the forest resource and these different values or perspectives lead to different conclusions when assessing the health of an ecosystem. Monitoring the condition of our forest resource is a complex task. The difficulty of measuring the health of our forest resources becomes quite obvious when attempting to report to lay people on the status of our forests. Maintaining an objective position when talking about forest health issues is equally difficult as we all have our biases on just how the forest should be used.

Forest resources can be evaluated from many different perspectives and using many different measures. Currently the most widely used measure of forest health is productivity. This is only **one** valid measure. Most foresters would argue that a 35-year-old red pine plantation that accrues 1.5 to 2 cords of volume per acre per year is in a very healthy state. A cross-country skier, on the other hand, may not be aware of the volume of wood fiber that the stand of trees is accruing but may notice the density of strait true stems reaching for sunlight and the lack of downed stems inhibiting his or her stride. A wildlife biologist charged with increasing the deer herd in the area may see this red pine stand as an impediment to productivity because of the lack of undergrowth for forage and cover. An insect pathologist would recognize the stand as a monoculture perhaps vulnerable to the next imported plant pest waiting for an opportunity at the most convenient point of entry. While all these perspectives are relevant to the health of this particular red pine forest, they all lead to different assessments of the condition of the resource.

To truly measure the overall condition of the forest resource, one approach would be to measure and integrate the following variables put forth by the National Forest Health Monitoring Program:

Ecosystem sustainability--The ability to maintain the desired condition. This could also be described as resiliency to stress. How well does the forest "spring back" from a pest outbreak?

Productivity--Physical output per unit of time for commodity and non-commodity products. Board feet of timber, wildlife demographics or the ability of a stand to sequester carbon are all examples of productivity.

Biodiversity--Species richness and species abundance--habitat suitability index would fall into this category.

Aesthetics--Big trees and hardwoods are valuable, saplings are often viewed as negatively affecting this measure.

Extent of ecosystems--How many acres of condition X do we have? How much do we need?

I am afraid that we fall quite short of the mark of being able to address all of the above issues in this document. It is however a significant start. To simplify reporting and to avoid conflict, it is necessary for us to describe conditions first and the particular values that a forest may offer second. This position gives us the ability to remain objective and not get mired down in a debate over the appropriate perspective. I hope you find the following pages informative and of value. Please direct comments and suggestions to me.

Frank J. Sapio, Program Manager--Forest Health
MDNR Forest Management Division
8th Floor Mason Bldg., Box 30452
Lansing, MI 48909-7952

1991-93 Forest Health Conditions: Michigan's Upper Peninsula

Robert L. Heyd, MDNR
Region I Forest Health Specialist

I. PEST REPORTS

OPENING SUMMARY: REGION I

The extreme drought beginning in the spring of 1987 and lasting through the spring of 1989 is still contributing to forest health problems in Michigan's Upper Peninsula.

The oak and aspen resource of the Upper Peninsula has been subjected to additional stresses. The forest tent caterpillar defoliated large tracts of forest land in 1989-90. Aspen was defoliated for a second time in 1989 by the large aspen tortrix. These stresses have produced weakly foliated aspen in many areas of the eastern Upper Peninsula. Our northern pin oak resource is still experiencing losses from the two-lined chestnut borer primarily in the southcentral Upper Peninsula.

Our maple resource is healthy where it occurs on suitable sites. Decline on stressful sites such as those with wet soils, sandy or very heavy soils, or shallow soils is evident.

The birch resource is largely an over-mature resource which experienced significant declines in the last few years. These declines and tree mortality results from the afore-mentioned drought, changing water tables, and frost damage to roots on soils without adequate winter snow protection.

The jack pine budworm is in the fourth year of a Lake States epidemic. Jack pines in the central and eastern Upper Peninsula have suffered greater damage than in the western Upper Peninsula. Some forest areas have been identified for salvage. These losses point to the need to manage jack pine on a 50-year rotation. Cyclic budworm outbreaks are a part of the jack pine ecosystem.

The years 1992-93 brought increased activity from lecanium scale, the birch leaf miner, the redheaded pine sawfly, the European pine shoot moth, and scleroderris canker. The later three call for diligence in monitoring and protecting investments in conifer regeneration.

Oak wilt control efforts have been successful with 236 epicenters controlled. Evaluation efforts continue to be hampered by extensive two-lined chestnut borer mortality.

The gypsy moth is moving en masse toward the eastern Upper Peninsula. We had our first impact in the Stalwart area--10 acres of light defoliation. The good news is an incentive being funded by the U.S. Forest Service to "slow the spread" of gypsy moth into the Upper Peninsula (see Slow-the-Spread: A Pilot Test for Michigan's Upper Peninsula).

PEST REPORTS: UPPER PENINSULA HARDWOODS

ASPEN *(Populus, spp.)*

Aspen and Balm-of-Gilead poplar were defoliated by the forest tent caterpillar (*Malacosoma disstria*) in Chippewa and Mackinaw Counties from 1988-1991. In 1989-90 they were defoliated for a second time in late summer by the large aspen tortrix (*Choristoneura conflictana*). These stresses in addition to the 1987-89 drought produced weakly foliated aspen in many areas. Balm-of-Gilead which grows on wetter sites experienced some level of stand mortality in many of these areas. The bronze poplar borer (*Agrilus liragus)* was associated with this mortality.

Forest Tent Caterpillar

The forest tent caterpillar (*Malaco-soma disstria*) (FTC) is found throughout the United States and Canada wherever hardwoods grow. Periodic infestations have been reported since 1835. It is the most widely distributed forest pest (insect) in North America. The forest tent caterpillar favors different hardwoods in different regions of the country. Oaks are favored throughout Michigan with aspen being preferred in the Upper Peninsula and sugar maple in northern lower Michigan. Less preferred hardwoods are

defoliated less severely or not at all. Widespread outbreaks occur at intervals from 6 to 16 years with each occurrence lasting 3 to 4 years.

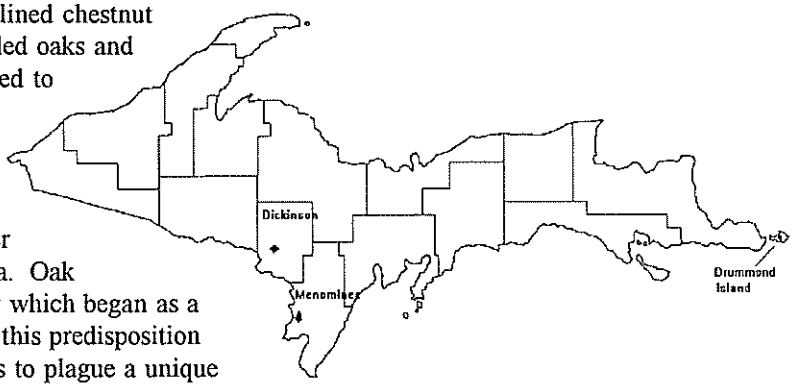
Forest tent caterpillar populations became epidemic in the western Upper Peninsula in 1987. The eastern Upper Peninsula experienced defoliation the following year. Peak years of defoliation were 1989-90 when as many as 700,000 acres were defoliated annually (see Table 1). Populations collapsed in most areas by 1992.

This epidemic began collapsing in 1991. Some visible defoliation was still evident in 1992 in the extreme eastern Upper Peninsula (Drummond Island), southern Menominee County, and southern Dickinson County.

Areas of northern Wisconsin bordering the central Upper Peninsula reported a resurgence of the forest tent caterpillar in 1993. No defoliation by the FTC was reported in the Upper Peninsula in 1993. The FTC overwinters as an egg mass attached to small branches in the crowns of favored hosts such as oak and aspen. The number of egg masses in tree crowns can be surveyed in the winter to predict the next year's population numbers. Based on these surveys, little defoliation is predicted in northern Wisconsin for 1994. Thus, based on historical trends, it should be several years before we see the next FTC epidemic.

The combined effects of the 1987-88 drought and the forest tent caterpillar defoliation predisposed two tree species, oak and balsam poplar, to losses from secondary pests. Secondary pests are those which attack already stressed hosts.

The two-lined chestnut borer killed oaks and contributed to oak decline in many areas of the Upper Peninsula. Oak mortality which began as a result of this predisposition continues to plague a unique



1992 Forest Tent Caterpillar Defoliation Areas

Table 1. Acres of Forest Tent Caterpillar Defoliation by Year and County.

County	Year				
	1988	**1989**	**1990**	**1991**	**1992**
Alger	11,400	62,080	13,960	***	----------
Baraga	640	5,062	---------	---------	----------
Chippewa	165,760	189,750	234,000	102,400	800
Delta	24,320	151,360	170,000	22,400	----------
Dickinson	21,270	4,640	5,120	3,520	2,500
Houghton	2,560	----------	----------	---------	---------
Keweenaw	800	----------	----------	----------	---------
Luce	7,040	29,760	10,400	640	----------
Mackinaw	65,920	31,040	60,160	23,030	---------
Marquette	12,160	152,540	62,840	760	---------
Menominee	2,320	39,040	53,680	42,880	4,000
Ontonagon	5,120	----------	----------	---------	----------
Schoolcraft	10,280	36,160	45,920	***	----------
TOTALS	329,590	701,432	656,080	195,630	7,300

*** Scattered pockets of defoliation--not mapped

10,000-acre northern pin oak resource in southwestern Menominee County (see Oak Mortality: Two-Lined Chestnut borer).

The bronze poplar borer caused scattered balsam poplar mortality in the eastern two counties of the Upper Peninsula (see Aspen).

OAK *(Quercus, spp.)*

Oak Mortality:

Two-Lined Chestnut Borer

Oaks in many portions of the Upper Peninsula were greatly stressed by the 1987-89 drought. Oak is a drought-intolerant species. This stress alone has predisposed oak to losses from secondary pests like the two-lined chestnut borer (TLCB) (*Agrilus bilineatus*) and Armillaria root rot (*Armillaria, spp.*). The forest tent caterpillar (FTC) (*Malacosoma disstria*) compounded this stress in 1989-90 by defoliating oaks throughout the Upper Peninsula. Small pockets of oak mortality have become a common occurrence since 1990.

The TLCB attacks the crowns and stems of weakened trees. The adult beetles lay eggs in the bark. The larvae bore into the inner bark, feeding between the bark and wood surface. This feeding disrupts the movement of food to the roots and water to the leaves. These borers first infest the upper crown. If tree vigor is not restored, the borer will kill the tree from the top down in one to three years.

The TLCB-caused mortality of pin oak in southwest Menominee County has been extreme since 1990. This area contains a 10,000-acre oak forest which is unique to the Upper Peninsula. In 1990, pockets of oak mortality ranged from several trees to 30 acres in size. There were about 300 acres of oak mortality in pockets larger than an acre. In addition, the entire oak resource had small clumps of mortality and single dead oaks scattered throughout.

Although 1991 through 1993 had near or above normal rainfall, oak stands with TLCB-caused dieback and mortality experienced additional dieback and mortality. To date, approximately one-third of this 10,000-acre oak resource has been adversely impacted.

Guidelines to Manage Oak:

1. Oaks with >50% crown dieback will likely die.

2. Oaks with 20% to 50% crown dieback which are infested by the TLCB are at high risk. Watering valuable trees and spraying for FTC or other defoliators (if needed) will reduce risk of tree mortality.

3. Do not open oak stands by cutting living trees. Opening a stand will increase soil moisture loss, further predisposing trees to TLCB and Armillaria losses. Armillaria is a root rotting fungus which colonizes residual stumps. Healthy stands can be thinned to increase vigor, but a full stocking should be maintained. (Consult a forester for further information.)

4. Remove and dispose of severely declining oaks by mid-July. Larvae are relatively young in early July and are very sensitive to rapid drying of host tissues. Felling in August or later allows larvae to survive until the next year.

5. Cover oak firewood produced from trees killed the previous year. Completely cover from May 1 to July 15 with a heavy plastic tarp, or remove from oak area.

7. Girdle living, infested oaks in May. The girdled tree will serve as a "trap tree" and TLCB beetles will lay eggs in them. These trees will dry before beetles can fully develop. Girdle trees close to the ground line. Bark areas below the girdle will support beetles for the next year's population.

8. In August or later, cut infested branches well below the dead portion of the branch. The larvae girdle the branch below where the leaves are brown. These materials should be burned before next May.

Oak Wilt in Menominee County

Oak wilt (*Ceratocystis fagacearum*) was detected in the Shakey Lakes area of Menominee County in 1981. This area has a 10,000-acre northern pin oak resource which is unique to the Upper Peninsula

Detection efforts from 1981 to 1990 revealed 236 infection centers--called epicenters. An epicenter is a single oak tree, or a group of oaks infected by the oak wilt fungus.

Oak wilt spreads to new areas from bark covered wood of trees killed the previous year. Spores are produced between the bark and wood after the tree dies. A small beetle called a sap beetle is attracted to the sweet smell of oak wilt spores. They carry these spores to a second attractant--fresh tree wounds. This "overland transmission" of oak wilt occurs primarily in May and June. Thus, a popular oak wilt prevention slogan is, "Don't prune in May or June!" If oaks are not wounded--by man or nature--at this time of the year, new epicenters can not be started.

Once oak wilt infects an oak tree through wounds, surrounding oaks can be infected via root-graft connections. Oaks growing in close association are often connected physically. Their roots cross and eventually bond as diameter growth forces merger of root tissues--called root grafting. Once this happens, the trees exchange fluids which include oak wilt spores.

Control efforts in the Shakey Lakes Area began in 1982. All 236 detected

epicenters now have vibratory plow lines established--known as root-graft barriers--to stop root-graft transmission of the disease. Oak wilt transmission between neighboring trees is effectively stopped by accurately locating and breaking root grafts between infected and healthy trees. A vibratory plow with a special 60-inch blade is used to insure that all roots are reached. (A vibratory plow is normally used to lay underground cable to a depth of 48 inches.)

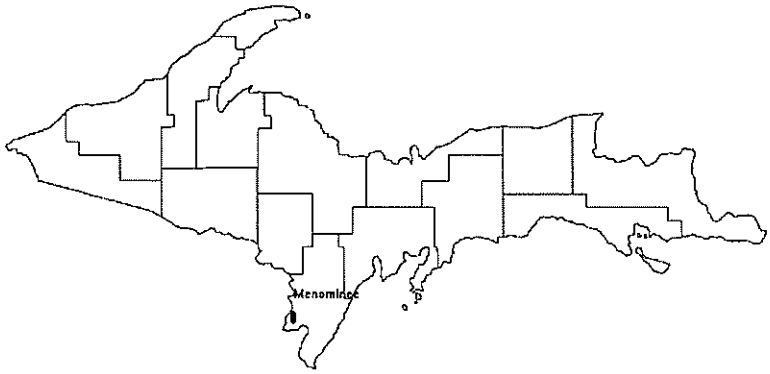
In addition to establishing root-graft barriers, infection epicenters are also controlled by killing or removing oaks inside the plow lines. This eliminates the chance for overland spread of oak wilt by insect-vectored spores and also removes the opportunity for formation of new root grafts between infected and healthy trees.

Cutting restrictions are in force on all state lands in the oak wilt-infected area during May and June. Harvest operations potentially wound residual oaks, providing a possible infection site. Restrictions will continue until all local sources of oak wilt spores are removed.

Over 5,000 trees have been lost either directly from oak wilt or indirectly by actions to control the disease. Many of these are valued landscape trees. Without this control program, we would lose much of this oak resource.

Because of another temporary--yet very serious--problem (see Two-Lined Chestnutborer) killing oaks in this area, the oak wilt project has been put on hold. Hopefully, 1994 will see significant recovery of this oak resource. If so, we will continue efforts to detect and treat any new oak wilt areas, and monitor the success of previous treatments.

This control project has been a cooperative effort funded by the Michigan Department of Natural Resources and the Michigan Department of Agriculture with support funding from the Menominee Board of Commissioners and Lake Township. Michigan Technological University supervised and researched control efforts. The Michigan State University Cooperative Extension Service, Menominee County, was instrumental in making landowner contacts and aiding in public relations.



Menominee County Oak Wilt Infected Area.

MAPLE *(Acer, spp.)*

Maple Decline

Declining maple can be found in areas of Michigan's Upper Peninsula. They are primarily associated with sites that consist of shallow, poorly drained soils over limestone or clay ridges or on sandy soils. Dead and declining trees may have wounds associated with the wound-invading fungi *Irpex mollis* and *Stereum gausapatum*. The prime sugar maple areas in northcentral and the western Upper Peninsula have fewer reported symptoms of decline.

The hundred-year drought event in 1987-89 helped define the types of sites that favor different tree species. Trees must endure the variations of temperature and rainfall that occur within their lifetime. Some trees--like jack pine--do well on drier, sandy sites. Sugar maple grows best on loamy soils. Thus, sugar maple seeds dispersed to less than optimum sites produced trees which were more likely stressed by weather extremes.

Sugar maple on marginal sites such as Kalkaska sands often occur as a mixture with other tree species such as hemlock, beech and red maple. The sugar maple and beech on these sites are showing signs of stress and decline as a result of the 1987-89 drought. With adequate rainfall these lower-quality sites can support good sugar maple growth, but dry years stress trees, resulting in decline with scattered mortality. These sites should be evaluated over time to determine sugar maple sustainability and productivity.

WILLOW *(Salix, spp.)*

Willow Blight

The "Soo" Forest Area in the eastern Upper Peninsula experienced a very destructive blight of willow known as Venturia *(Pollaccia salicperda)*. New shoots are infected in the spring as they emerge. Both shoots and leaves blacken and shrivel. Black elliptical cankers may also develop on older parts of the shoots and on previous year's twigs. The degree of infection depends upon the spring weather. Rainy weather is especially conducive to disease

development. Diseased twigs and branches can be pruned during late winter. Selective pruning eliminates diseased portions which can reinfect next year's shoots. Pruning also thins crowns, allowing more air flow to dry leaves and branches. Never permit lawn sprinklers to wet willow leaves. A broad spectrum fungicide applied several times in the spring beginning at bud break and every 10 to 14 days after can minimize severe infections on valuable trees.

PEST REPORTS: UPPER PENINSULA CONIFERS

PINE *(Pinus, spp.)*

Redheaded Pine Sawfly

The redheaded pine sawfly *(Neodiprion lecontei)*, is a serious pest of red, jack and Scots pine plantations. The sawfly larvae consume both new and old needles in mid-summer. A complete defoliation kills small trees while less extensive feeding results in poor diameter growth and the death of defoliated branches. Extensive mortality can occur in young pine plantations during periodic epidemics. Heaviest infestations are commonly on pines growing under stressful conditions due to poor soils and/or competitive vegetation such as sod, dense bracken fern or overstory trees.

The redheaded pine sawfly became epidemic in several red pine plantations in the southcentral Upper Peninsula in 1992-93. Several plantations were sprayed both years. Egg and early larval surveys were conducted in late June to early July to determine the size of sawfly populations. An approved insecticide was applied 7 to 10 days after the emergence of the first larvae. Optimum timing for spraying is during the second larval instar. Approximately 80 acres were sprayed in 1992 and 200 acres were sprayed in 1993.

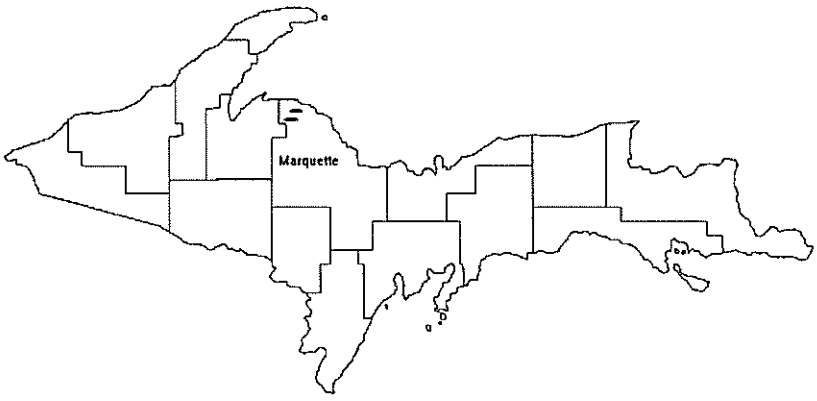
Scleroderris Canker of Northern Conifers

The Lake States' strain of scleroderris canker *(Ascocalyx abietina)* was epidemic on approximately 3,600 acres of plantation jack pine in northern Marquette County in 1992 (see map).

Scleroderris infects branches through the needles. Spores are wind-blown or rain-splashed. Branch cankers are apparent when bark is removed from infected branches (brown foliage). Trees less than 6-feet tall can be killed. Humidity at levels higher than 6 feet in a plantation is too low to favor infection.

Jack pine branch mortality ranged from a few scattered shoots to all the lower level branches to a height of 3 to 4 feet. This represented mortality of one-half to one-quarter of the trees crown in the more severely affected areas. Tree height averaged 6 to 15 feet. This branch mortality did not kill trees. Red pine in this area were less severely affected.

Scleroderris was much less severe in this area in 1993. Scattered pockets of trees with a few brown branchlets were noted. The sudden reduction in severity may be due to little host material being available low to the ground where humidity favors infection.



1992 Scleroderris Canker Infected Areas

White Grub Damage on Tree Seedlings

White grubs *(Phyllophaga, spp.)*, are destructive pests in some young red and jack pine plantations in the Lake States. White grubs are the larvae of the "June bug", or more accurately the June or May beetle. They are a problem in the reforestation of poorly stocked hardwood stands and old abandoned fields where they live in the soil and feed on tree roots and other vegetation.

White grubs damage seedlings by chewing off smaller roots and girdling larger roots. The result is reduced growth and, occasionally, extensive mortality. The loss of growth is often underestimated, and can be significant. Protecting tree seedlings during the first two years of establishment with insecticides, delaying planting, or not planting infested sites are control options.

Grub population numbers fluctuate. Monitoring grub numbers and waiting for acceptable conditions for planting is labor intensive and costly in terms of lost growing time. There is no guarantee on some sites that numbers will drop below threshold levels. Because of this, environmentally acceptable pesticides and application methods are a desirable option.

Chemical and biological insecticides, and different application methods have been used to establish long-term growth studies. Several materials have been effective in reducing seedling mortality. However, it is difficult to assess the degree of protection of seedling roots. Seedling growth is used as an indicator of rootlet mortality. Vigorously growing seedlings indicate little rootlet damage; whereas, stunted growth reflects a commensurate degree of root damage. Seedling growth over time is being monitored to evaluate the benefits of treatments versus no treatment control areas. The results of these studies will help clarify the economics of control decisions.

Two new, promising biological control materials have surfaced. One is a strain of the bacterium, B.t. (*Bacillus thuringiensis*), and the other an insect-feeding nematode (*Steinernema feltiae*; *Heterorhabditis heliothidis*). These may offer the most environmentally acceptable alternatives, and may resolve the problem presented by the more short-lived chemical insecticides currently available. Two years of seedling protection is needed. With the removal of long-term residual chemical insecticides like the chlorinated hydrocarbons (i.e. DDT, Aldrin), control of grubs is limited to one to three months, or one growing season. These new biologicals offer the hope of carry-over into the next season. They would also be safer materials for tree planters to handle.

Pine Engraver Beetles

Pine engraver beetle *(Ips pini)* populations are much reduced from the drought years of 1987-89. The pine engraver kills red and jack pines by damaging the inner bark of weakened or damaged trees. Near normal rainfall beginning in 1991 has increased tree vigor. This vigor has reduced bark beetle populations to endemic levels. Vigorous trees do not attract beetle attacks, and can better withstand other stressing factors.

Salt Injury

Every spring, roadside conifers display the effects of winter applications of road salt. White pine is especially sensitive. Brown or missing needles are the most visual symptoms. Foliage facing the road is most severely affected. The entire tops of smaller trees may be browned if close to the road. Lower branches protected by snow cover are unaffected. Winds can carry salt-laden splashes and mists toward the tops of the tallest white pine and to trees well off the road rights-of-way. A prevailing wind pattern may cause more extensive white pine injury on one side of the road.

Salt injury does not generally kill trees, but can reduce tree vigor and growth.

SPRUCE *(Picea, spp.)*

Yellow-Headed Spruce Sawfly

The yellow-headed spruce sawfly (YHSS) (*Pikonema alaskensis*) has been active for the past five years in the Upper Peninsula. It defoliates small spruce--seriously degrading spruce Christmas trees. Vigilant monitoring is advised. Eggs are usually laid as bud caps are shed. Larvae then emerge in the next 7 to 14 days--but can emerge as late as July. For valued ornamental trees, spray larvae with an approved insecticide. If larvae are very small, either wait a few days to spray to insure complete egg hatch, or spray and continue to monitor and spray again if additional larvae are detected. Monitor for 2 to 3 weeks after initial egg hatch. Christmas tree plantations with YHSS can be sprayed 10 days after bud caps are shed with a material which has a residual effect for 2 to 3 weeks like Sevin XLR (XLR stands for extra long residual).

MINOR PEST PROBLEMS: REGION I

Michigan's Upper Peninsula

1991 - 93

PEST PROBLEM	TREE SPECIES	COMMENTS
Armillaria Root Rot *(Armillaria mellea)*	Jack Pine Red Pine	Scattered mortality in young pine.
Birch Leafminer *(Fenusa pusilla)*	White Birch	Populations more widespread, with locally heavy defoliation.
Bronze Poplar Borer *(Agrilus liragus)*	Balm-of-Gilead	10-20% mortality on poorly drained lowlands in eastern U.P.
Eastern Tent Caterpillar *(Malacosoma americanum)*	*Prunus, spp.* *Malus, spp.*	Population collapse.
European Pine Shoot Moth *(Rhyacionia buoliana)*	Red Pine	Several occurrences reported after many years of little activity.
Hypoxylon Canker *(Hypoxylon mammatum)*	Quaking Aspen	Common problem.
Large Aspen Tortrix *(Choristoneura conflictana)*	Quaking Aspen	1992 widespread, low-level occurrence. 1993--little problem.
Lecanium Scale (several genera)	Sugar Maple	Widespread, high population numbers in 1992 only.
Pine Root Collar Weevil *(Hylobius radicus)*	Scots Pine	Limits Scots pine as reforestation species.
White Grubs *(Phyllophaga, spp.)*	Jack Pine Red Pine	Many reports of regeneration impacts including mortality in 1992.
White Trunk Rot of Aspen *(Phellinus tremulae)*	Quaking Aspen	A large portion of aspen resource is mature to over-mature.

II. PROJECT REPORTS

WHITE BIRCH RESOURCE EVALUATION

Michigan's Upper Peninsula

White birch *(Betula papyrifera)* is experiencing a decline throughout the Lake States. The public and forest industry are concerned over the long-term condition and availability of white birch. From a forest health and management perspective, we need better answers concerning the severity and causes of this decline. Findings could alter current concepts of white birch timber supply and allowable cuts on managed lands.

The Michigan Department of Natural Resources initiated a survey of Upper Peninsula white birch in 1992. The purpose of the survey was to evaluate the health of the white birch forest resource. Support funding for this study was provided by the U.S. Forest Service, Northeastern Area, State & Private Forestry.

METHODS

The condition of birch stands on high-quality, undisturbed birch sites was evaluated. Finding good birch sites in good condition would support the hypothesis that much of the observed birch decline and mortality was occurring on less than optimum sites. We would then search for initial risk-rating criteria using site quality to predict decline occurrence, and possibly, decline severity. If we found that our good birch sites were declining, further evaluations and greater concern commensurate with the findings would be warranted.

Twenty-five birch stands were selected in the central and western Upper Peninsula in 1992 and 17 in 1993. Each stand was traversed at 5-chain intervals. Variable radius plots were taken every 5 chains (one plot per 2.5 acres) using a 10-factor prism.

The basal area was recorded for each plot. All trees were identified to species and rated in one of two crown position categories--Dominant/Codominant or Intermediate/Suppressed. Trees were then placed into one of the following damage or decline categories by recording the number of 8-foot sticks per tree:

1 - Up to two dead branches

2 - Three dead branches to < 15% dead crown

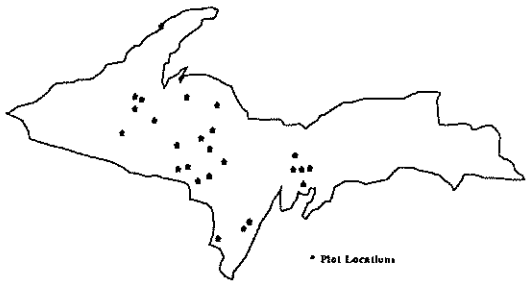
3 - 15% to 30% dead crown

4 - 31% to 60% dead crown

5 - > 60% dead crown

6 - Dead tree with branches

Figure 1. Plot Locations



Birches quickly drop branches after dying. Dead birches with branches remaining were presumed to have died within the last year. Thus, Damage Category 6 trees represent current mortality.

Survey results from the Wisconsin Department of Natural Resources indicate that birches with declines of less than 30% have recovered the following year. Thus, Decline Categories 4 and 5 likely represent trees at significantly greater risk of dying. Birches in the >60% decline category will probably die. Birches in the 31-60% category are at a greater, yet undefined risk of dying.

RESULTS

Birch Resource. According to the 1980 U.S. Forest Service, Forest Inventory and Analysis Survey, the Upper Peninsula's 254,300 acres of paper birch represent 68% of Michigan's birch resource. Michigan experienced less than 1% birch mortality from 1966 to 1980. Upper Peninsula ownership is distributed as follows:

Ownership	Acres
Federal	42,600
State	50,400
Forest Industry	53,500
Other	108,800
Total	254,300

According to the Michigan Department of Natural Resources Inventory of State Forest Lands, Upper Peninsula state forests contain 157,000 acres of forest with at least 10-square feet of paper birch. Birch represents a minimum of 5-10% of the trees in these stands. Within this acreage, 44,800 acres (28%) have a large enough birch component to be managed specifically for paper birch regeneration.

Mortality & Decline. Seventeen birch stands were surveyed in the

central and western Upper Peninsula in 1993. Three hundred six plots were sampled on 766 acres. The average stand age was 68±8 years. The average site index (50) was 58±9. The average basal area was 116±27 for all tree species. The average volume was 34±7 cords/acre. Birch comprised 50%±18% of the basal area and volume (see Table 1).

Mortality and decline data are presented in Tables 2 and 3. The current year's mortality (Dead) for all tree species averaged 3.0±1.8 cords/acre (Table 2). Birch mortality alone averaged 2.3±1.7 cords/acre. Species other than paper birch represented 0.7 cords/acre or 23% of the surveyed mortality.

The current year's mortality for all species was 8.9%±7.1% of the volume (Table 3). The birch component was 7.1%±6.9% of the all species volume, or 13.8%±8.8% of the birch volume alone.

There was a 2% increase in overall birch mortality from 1992 to 1993. This equates to 0.6 cords/acre of additional loss.

If trees with greater than 60% dead crowns were added to current mortality (Dead +), loss estimates increased by 0.3 to 3.3±1.8 cords/acre (Table 2). Birch loss alone increased by 0.3 to 2.6±1.7 cords/acre. Thus, the increase was primarily due to birch decline (see Figure 2).

When trees in the 31-60% decline category are added to the >60% decline category and current year's mortality (Dead++), the possible loss estimate increased by 0.7 to 3.7±2.0 cords/acre (Table 2). Birch alone accounts for 0.6 cords/acre and tree species other than birch account for only 0.1 cords/acre, or 17%, of this difference.

Overall, 0.8 cords/acre, or 22%, of the combined current year's mortality and the 31-60% and >60% decline categories is accounted for by species other than paper birch (see Non-Birch, Figure 2). These other tree species were primarily represented by balsam fir, but also included aspen, white spruce, black cherry and sugar maple.

Tree Dominance. Dominant and codominant trees accounted for 91%±6.77% of the birches surveyed. Intermediate and suppressed trees represented 9%±6.7% of the birches surveyed. There was no apparent effect of tree dominance on birch mortality or decline.

DISCUSSION

The following summary comments come from *Silvics of North America: Volume 2. Hardwoods*, Ag. Handbook 654, Dec 1990:

> Mortality is heavy throughout the life of a paper birch stand. It is a shade-intolerant tree usually lasting only one generation and then is replaced by more tolerant species. Birch trees respond to stress by losing leaves. Stands approaching maturity--more than 60 years--seldom respond to a thinning. Post logging decadence--a condition resembling birch dieback--sometimes develops in residual trees following partial cutting. Thin at an early age, but avoid thinning in mature, previously untreated stands.

Table 1. Survey Results by Forest Area and Total Project (1993).

County	Number of Stands	Number of Plots	Acres	Age	Site Index	Cords/Acre	% Birch	Basal Area
Baraga	6	138	345	69	58	31	58	101
East Iron	4	48	120	65	58	34	47	112
Dickinson	4	77	193	71	64	34	49	118
Marquette	3	43	108	64	62	42	43	150
Total	17	306	766					
Average				68	58	34	50	116
Standard Error (n=17)				8.2	9.2	7.2	17.8	26.9

Table 2. Cords/Acre for All Species Vs. Birch Only Within Damage and Decline Categories by Plot, Forest Area, and Total Project (1993).

County	All Trees				Birch Only			
	Total	Dead	Dead+	Dead++	Total	Dead	Dead+	Dead++
	Cords/Acre				Cords/Acre			
Baraga	31.4	2.9	3.5	4.2	16.8	2.3	2.8	3.3
East Iron	33.6	4.2	4.5	4.9	14.3	3.1	3.4	3.8
Dickinson	33.7	1.8	1.9	2.1	16.4	1.5	1.6	1.7
Marquette	42.0	3.0	3.3	3.5	17.9	2.3	2.6	2.8
Average	35.2	3.0	3.3	3.7	16.4	2.3	2.6	2.9
Standard Error	7.2	1.8	1.8	2.0	3.2	1.7	1.7	1.7

(NOTE: Dead = Mortality or Decline Category 6; Dead + = Mortality + Decline Category 5 (> 60% dead crown); Dead++ = Mortality + Decline Category 4 (31% to 60% dead crown) + Decline Category 5.

Table 3. Mortality of All Tree Species and Birch Only as a Percent of All Species Volume and Percent Birch Volume Lost (1993).

County	All Species Volume		Birch Volume
	% All Species	% Birch	% Birch
Baraga	8.8	7.1	13.1
East Iron	14.3	11.3	20.0
Dickinson	5.5	4.4	9.1
Marquette	7.1	5.6	13.1
Average	8.9	7.1	13.8
Standard Error	7.1	6.9	8.8

The following summary comments come from *Experiments on the causal mechanisms of dieback on deciduous forests in Quebec,* Forestry Canada, Information Report LAU-X-96, 1991, Rene Pomerleau:

> At the beginning of the 1940's an estimated 1400 million cubic meters of yellow and paper birch were lost in a decline affecting Canadian forests. Climatic factors were primarily responsible. In certain winters, soil had no protective blanket of snow. Consequently, it froze to a depth of 1.27 m (50 in.) and the root systems of shallowly rooted trees like paper birch were damaged. This was especially true of birches on wet or thin soils. Root systems deteriorated in the frozen soil because of ice lens raised roots. Also, roots embedded in frozen soil were killed by desiccation when the crown was subject to summer-level temperature and light conditions. This resulted in both root mortality and desiccation of the trunk and crown in the spring. In the worst cases, trees died after a season, or one or two years later, especially if the same conditions recurred the following winter. Severely stressed trees had secondary infections which prolonged the decline until the tree died.

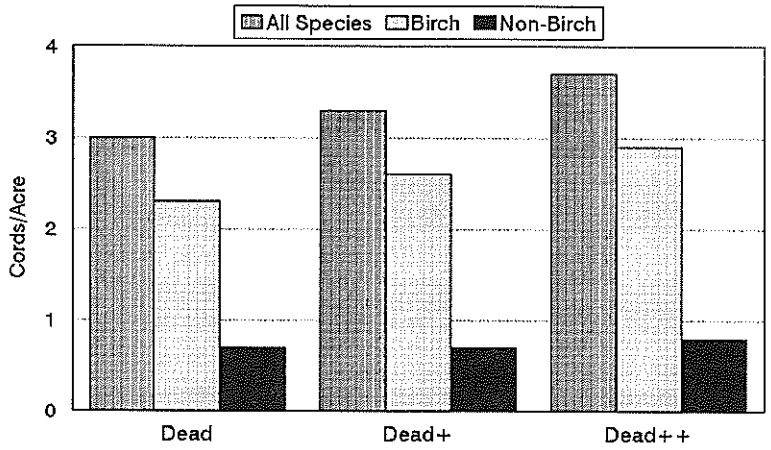
Many moderately stressed trees recovered gradually, developing a new root system and normal crown once dead branches fell. Young birch seedlings recovered even when all leaves were withered and the top was bent and dry.

Upper Peninsula. Paper birch growing on stressful sites--shallow soils, rocky ridges, poor soils, exposure to strong winds--have been declining and dying since the mid-1980's. Until this survey, the decline was perceived to be a result of the many acres of birch we have growing on stressful sites. This, in combination with the age of this mature resource, was producing the expected result--the loss of a stressed, over-mature birch resource. The survey results indicate, however, that birch decline is occuring on high-quality sites as well as stressful sites.

The extended drought years of 1988-1990 predisposed many tree species to secondary insect and disease problems. Two winters in the 1988-1991 period brought early, extreme cold temperatures with little snowfall, resulting in record depth of soil frost. The combination of these events likely contributed to widespread birch decline and mortality in the Lake States. This predisposed the birch resource to secondary insects and diseases.

Birch Resource and the Public. As stated in the preceding section titled Results: Birch Resource, 72% (112,000 acres) of the Upper Peninsula state forest land with birch has only a minor birch component and is not managed with the objective of regenerating birch. Even so, birch is a very visible (noticed and admired) component in these stands because of their white bark. Thus, when these shade-intolerant, mature trees decline and die from natural successional forces or other environmental stresses, it is noted by a concerned public. Birch decline is especially evident along travel corridors where birch occur on highly visible ridges and bluffs. These can be very stressful sites.

Figure 2. 1993 White Birch Loss Assessment: Average Volume Reductions by Damage Categories and Tree Species.



Note: Dead = current year's mortality; Dead+ = mortality + Decline Category 5 (> 60% dead crown); Dead++ = mortality + Decline Category 4 (31% to 60% dead crown) + Decline Category 5.

Mortality & Decline. The birch stands evaluated on good sites in this survey averaged 2.3±1.7 cords/acre of the current year's mortality (1993). By combining the dead trees and trees with greater than 60% decline we derived a loss of 2.6±1.7 cords/acre (see Birch, Figure 2). This represented a loss by mortality of 13.8% of birch volume, or an estimated loss of 15.8% of birch volume if the >60% decline category is included. The additional 2% of the birch volume reported in the 31-60% decline category represents an undefined impact. Some portion of this will likely be lost.

These figures are project averages, with much variation in losses and declines from stand to stand. Mortality and decline did not correlate with inventory information on stand age or site index, or surveyed species composition on these excellent birch sites.

Tree Dominance. There were no significant differences in decline or mortality between dominant/codominant and intermediate/suppressed trees. This decline affected the entire stand structure. It is not a successional pattern which might be expected with weaker, less dominant trees succumbing--or older, maturing trees with less vigor succumbing. Trees of all size classes were equally affected.

SUMMARY

The Upper Peninsula has and still is experiencing a significant decline of its birch resource. This decline is affecting both good and poor birch sites. Losses on poor sites are much more severe. Losses on good birch sites averaged 2.3 cords/acre or 13.8% of the birch volume. The remaining portion of stands on good sites are recovering with some minor additional losses expected.

Twenty-three percent of the reported mortality was non-birch species.

Much of this was balsam fir, a species known for its shallow rooting habit. Understory balsam fir mortality in response to a severe drought is well documented. This further supports the concept that this decline is likely the result of climatic extremes of the 1980's and early 90's.

The Upper Peninsula's birch resource is mature to over-mature. Birch is a short-lived, shade-intolerant, pioneer species. Stressful sites shorten life span as witnessed along travel corridors, in open areas around water where soils are shallow, or on rock outcrops. It may be difficult for younger, regenerating birch to compete with more long-lived, shade-tolerant species. White birch is a desired component of Upper Peninsula forests even though it may not be as valuable as timber as some of the more shade-tolerant species. It is native to the region and has a long history as part of the mixed coniferous-hardwood forests of the North. Native Americans used white birch to build canoes and for various other purposes. Its aesthetic and wildlife values can not be overestimated. The future success of the Upper Peninsula's white birch resource will depend upon the activities of man and upon the forces of nature. Efforts should continue to study birch decline and to develop forest management guidelines that will support the regeneration of white birch.

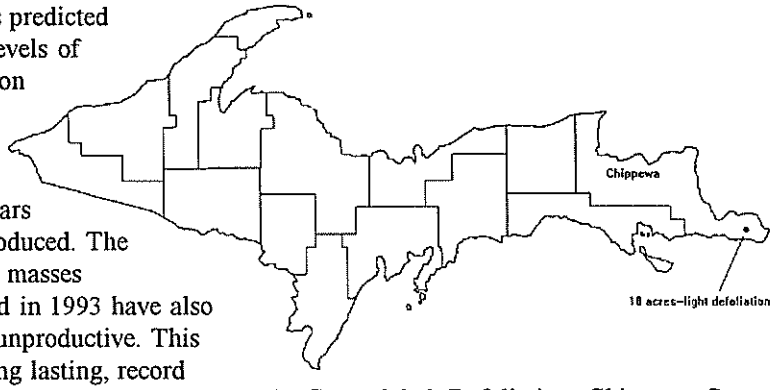
THE GYPSY MOTH

Michigan's Upper Peninsula

The gypsy moth (*Lymantria dispar*) feeds on the leaves of many types of hardwood trees. It was originally introduced into the northeastern United States from Europe in 1869. Efforts to use it to improve silk production failed. Its escape into the forests of North America has proved costly. Gypsy moth caterpillars can be annoying, especially during outbreaks. Hordes of caterpillars feeding on hardwood trees and understory shrubs invade campgrounds and other wooded dwellings--including urban areas. Egg masses and pupal cases are found attached not only to trees, but to outdoor furniture, buildings and anything that provides a convenient resting place for the ovipositing adult moths or pupating caterpillars. Hairs on the caterpillars and egg masses cause skin rashes and allergic reactions in some people. In addition to these nuisance values, unhealthy trees are weakened by repeated defoliation. This makes them susceptible to other insect and disease problems that can kill severely weakened trees. A healthy hardwood tree can be stripped of all its leaves for two or three years in a row without being killed. Healthy trees have nutrient reserves which are used to replace leaves lost by defoliation. In 1981, a record 12.9 million acres were defoliated by gypsy moth in the United States.

The gypsy moth's steady westward movement reached Michigan in 1954. The gypsy moth can now be found throughout the Lower Peninsula and in a few areas in the eastern Upper Peninsula.

Gypsy moth defoliation was first detected in the Upper Peninsula in 1992. About 10 acres of mixed oak and aspen was lightly defoliated (see map). This area near Stalwart in Chippewa County was not reported in any of the 1992 aerial surveys and was not defoliated the next year (1993). It is thought that unusually cold weather in 1993 may have slowed insect development with fatal results. Although eggmass numbers predicted higher levels of defoliation for 1993, few caterpillars were produced. The few egg masses produced in 1993 have also proved unproductive. This time, long lasting, record cold temperatures during the winter of 1993-94 (30-50 below zero F) killed many of the eggs.



1992 Gypsy Moth Defoliation, Chippewa County

A few other sites with a handful of egg masses have been detected in other areas of the extreme eastern Upper Peninsula. The gypsy moth is slowly moving into the Upper Peninsula from the heavily infested Lower Peninsula. For this reason among others, a gypsy moth control pilot project known as "Slow-the-Spread" was established in the Upper Peninsula in 1993. The purpose of this project is to use existing technology to slow the westward spread of the gypsy moth.

SLOW-THE-SPREAD: A PILOT TEST FOR MICHIGAN'S UPPER PENINSULA

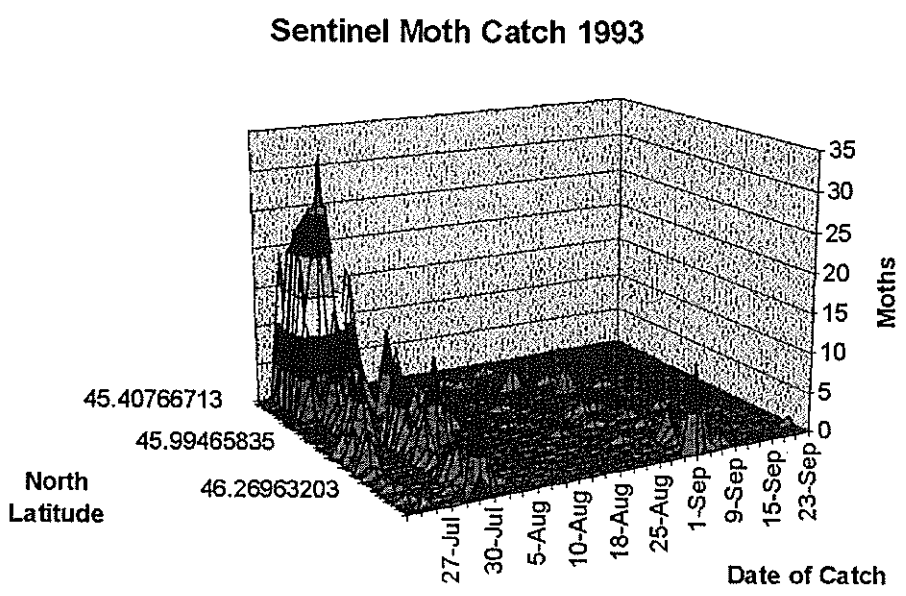
Frank J. Sapio (MDNR)

In the spring of 1993, Michigan joined a four state pilot project to determine if we can economically slow the spread of gypsy moth. The "Slow-the-Spread" project, which uses environmentally benign techniques such as intensive male moth monitoring, mating disruption, and perhaps *Bacillus thuriengiensis* (BT) and Gypcheck[tm], brings several state and federal agencies under one umbrella. The Michigan Department of Agriculture (MDA) has agreed to conduct all monitoring of male moths and any BT treatments that may be needed. The Michigan Department of Natural Resources aids in all training, works on technology development and has agreed to carry out any ''non-standard'' intervention techniques such as mass trapping and other mating disruption. Michigan State University manages all our data and has developed the public education component of the project. The US Forest Service provides the funding for this project as well as representing a significant land management interest. This project crosses many ownerships and is partially located on the Hiawatha National Forest and Escanaba River State Forest.

In 1993 we began this project with four trap tenders all using global positioning (GPS) technology to locate the traps and collect any necessary data. We found GPS to be a useful tool providing a level of efficiency and accuracy that we are not able to meet without the technology. GPS was a real success.

Sentinel traps maintained by Jim Pawlawicz and Norm Remington of the MDA documented some unusual moth activity that indicated a massive migration of male moths. This phenomenon significantly confounds our data making it very ''noisy'' and difficult to interpret.

These data sorted by north latitude across dates indicates two separate periods of flight activity. Major flight appears early on in the season in the south area of the project. This area of major activity happens to occur on the southern shore of the Upper Peninsula on Lake Michigan. Predicted moth flight based on phenological models would put local moth flight toward the end of September, which coincides with our second period of moth activity. We believe that this first peak of moths is due to moths being blown in from the Lower Peninsula as it coincides with Lower Peninsula flight. Short of marking and releasing moths most of our evidence will continue to be circumstantial. Next year we plan to use different trapping techniques and the wizardry of geographic information systems (GIS) to help sort out the data. Until then, slowing the spread of gypsy moth will be a very difficult task indeed.



JACK PINE BUDWORM

Jack pine budworm (*Choristoneura pinus*) regularly defoliates large acreages of jack pine *(Pinus banksiana)* in the Lake States. Resulting growth loss and tree mortality is influenced by a variety of factors. Old, open-grown trees, suppressed trees, and slow-growing trees, are more likely attacked and damaged by attacks. Vigorous, young, well-spaced, even-aged stands are much more resistant. Suggested rotation age for jack pine in the Lake States is 50 years. This combined with good silvicultural practices which produce vigorous, well-stocked, even-aged stands effectively reduces resource impacts caused by cyclic budworm outbreaks. Historically, a budworm outbreak in a susceptible stand kills 10 to 40% of the merchantable trees; kills most of the understory or suppressed trees; reduces growth 50% the first year and 100% each year thereafter; and, precludes seed production for up to three years after the outbreak subsides.

The Insect and Its Damage

Budworm larvae begin feeding in male cones in May. Defoliation is evident by mid-June. The larvae usually finish feeding by early July. Clipped needles webbed to the branches are brown--highlighting defoliated crowns with a red to brown cast. This coloration is lost as heavy rains and wind remove clipped needles from the canopy.

The budworm populations began building in isolated areas of Michigan's Upper Peninsula in 1986-88. Expected damage in 1989 did not materialize. The unusually cold, damp spring of 1989 caused heavy mortality of young budworm larvae. The budworm exploded upon the scene again in 1991. The 1991 epidemic occurred simultaneously throughout the Lake States. The first-year damage to jack pine was severe in areas of northern Luce and southeast Marquette Counties of Michigan's Upper Peninsula.

Luce and Marquette Counties experienced a second year of moderate to heavy defoliation in 1992. Populations collapsed in Luce County and previously defoliated areas in Marquette County in 1993. However, new areas in southwest Marquette County were extensively damaged. East Iron County was also defoliated in 1993 (Figure 1; Table 1).

Areas in the Upper Peninsula that were heavily defoliated in 1991 were lightly defoliated in 1992. Whereas, lightly defoliated areas to the east of areas heavily defoliated in 1991 were heavily defoliated in 1992. Aerial surveys of the Upper Peninsula detected 47,690 acres of 1991 defoliation, 19,960 acres in 1992, and 19,460 acres in 1993. Figure 1a shows the approximate locations of 1992 defoliation within each county. Figure 1b is drawn somewhat more to scale and shows the locations of 1993 defoliation.

A list of jack pine stands sorted by cordwood volume and risk of jack pine budworm loss was given to each district and area office to help set cutting priorities.

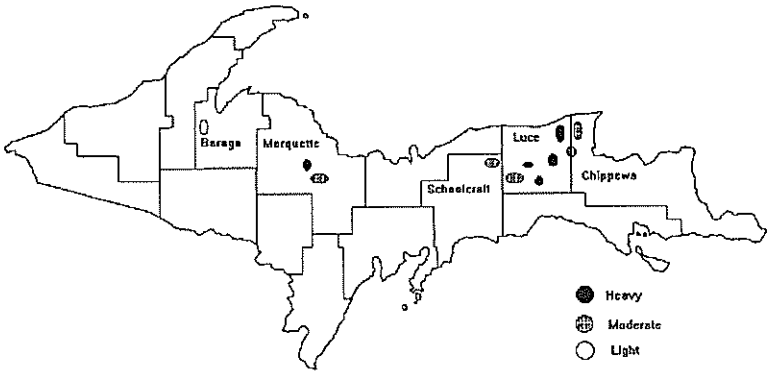


Figure 1a. 1992 Jack Pine Budworm Defoliation.

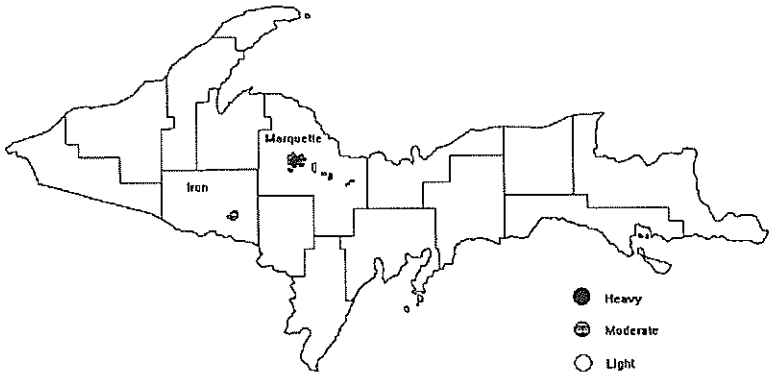


Figure 1b. 1993 Jack Pine Budworm Defoliation.

JACK PINE BUDWORM IMPACT SURVEY

Current and projected tree mortality caused by jack pine budworm defoliation was assessed in Michigan's Upper Peninsula beginning in 1991. The survey was improved and repeated in 1992-93. Heavily defoliated jack pine stands were selected in areas of Luce and Marquette Counties.

Methods

Each forest stand was traversed at 5-chain intervals. Variable radius plots were taken every 5 chains (one plot per 2.5 acres) using a 10-factor prism. The basal area was recorded in each plot. All trees were identified to species and placed in one of two crown position categories--Dominant/Codominant or Intermediate/Suppressed. Trees were further placed into one of the following damage categories by recoding the number of 8-foot sticks in the tree:

First-year feeding damage categories:

Light -- Little or no back feeding*; brown cast.
Moderate -- Back feeding in top 1/2 of crown only.
Heavy 1 -- Back feeding on > top 1/2 of crown.
Heavy 2 -- Back feeding only in bottom 1/2 of crown.

Second-year feeding damage categories:

Light -- New growth throughout tree; little feeding; last year's back feeding in upper 1/2 of crown may be evident.
Moderate -- New growth throughout tree with light brown cast; last year's back feeding in upper 1/2 of crown evident.
Heavy 1 -- New and old growth in top 1/2 of tree sparse.
Heavy 2 -- Green needles in bottom 1/2 of crown only; tree tops with grayish cast.
Dead -- No living branches.

* Back Feeding = consumption of older needles once current growth is eaten.

Table 1. Acres of 1992-93 Budworm Defoliation

County	Defoliation Class	Acres 1992	Acres 1993
Baraga	Light	1,200	0
Chippewa	Moderate	1,700	0
Iron	Moderate	****	1,700
Luce	Moderate	8,600	0
	Heavy	4,800	0
Marquette	Light	****	3,150
	Moderate	1,400	4,850
	Heavy	760	9,760
Schoolcraft	Moderate	1,500	0
SUBTOTALS	Light	1,200	4,850
	Moderate	13,200	4,850
	Heavy	5,560	9,760
TOTAL ACRES		19,960	19,460

Results and Discussion

1991 Survey

The 1991 survey revealed that 73% of the merchantable trees in the most heavily impacted stands were lightly to moderately defoliated the first year. The Heavy 1 and Heavy 2 categories had 18% and 9% of the trees, respectively. There was little mortality in the first year of the budworm epidemic. The Heavy 2 category trees represented likely mortality. Further evaluation of trees in both heavy defoliation categories found viable buds throughout the crowns of most of the trees in the Heavy 1 category and some of the Heavy 2 category trees. Thus, it was concluded that unless stressed by other factors such as drought and secondary pest problems, the resource would largely recover from this first year defoliation in 1991.

1992 Survey

Twenty-two stands were sampled in Luce, Schoolcraft and Marquette Counties. Three hundred and one plots were visited representing 750 acres. The average stand age was 61±10 years the average site index (50) was 53±6 and the average basal area was 83±12 (see Table 2). The average stand volume was 17.9±3.7 cords/acre.

Mortality and damage data are presented in Table 3. Current mortality (Dead) averaged 1.4±0.9 cords/acre. Projected losses are estimated by adding the Heavy 2 (H2) category trees to mortality. The average projected losses (Dead + H2) were 2.6±1.7 cords/acre. Projected losses ranged from none to 6.6 cords/acre.

Percent mortality (Dead) in Table 4 averaged 7.5±4.6% of total volume. Projected percent losses from mortality (Dead + H2) averaged 14.4±11.1%. Percent projected losses ranged from none to 44.6% of the total volume.

Table 2. Inventory Statistics Summarized by County and Project (1992 Survey).

County	Number of Stands	Number of Plots	Acres	Age	Site Index	Basal Area	Cords per Acre
Luce	12	198	485	64	50	84	18.2
Schoolcraft	2	17	45	56	51	87	18.8
Marquette	8	86	220	64	59	77	16.8
Totals	22	301	750				
Averages				61	53	83	17.9
Standard Error (n=22)				10	6	12	3.7

The greatest losses were in low volume, poorly stocked, storied stands. Only two stands exceeded 2 cords/acre current mortality. Projected losses of 2 cords/acre were exceeded in 11 of the 22 stands, 6 stands exceeded 3 cords/acre. Three stands exceeded 10% mortality of total volume. Eight stands exceeded a 15% projected loss of volume.

The distribution of cordwood volume within damage and tree dominance categories is significant. Dominant/ codominant trees contained 94% of the stand volume. The more

Table 3. Cords/Acre per Damage Category Summarized by County and Project (1992 Survey).

County	Number of Stands	Cords/Acre Total	Living	L	M	H1	H2	Dead	Dead+H2
Luce	12	18.2	17.3	11.6	2.2	2.5	1.0	0.8	1.8
Schoolcraft	2	18.8	17.2	11.1	2.9	2.2	1.0	1.6	2.6
Marquette	8	16.8	15.1	10.5	1.6	1.5	1.5	1.7	3.2
Averages		17.9	16.6	11.1	2.2	2.1	1.2	1.4	2.6
Standard Error (n=22)		3.7	3.6	4.5	1.5	2.2	1.4	0.9	1.7

Table 4. Damage Category Volumes as a Percentage of Total Volumes by County and Project (1992 Survey).

County	Number of Stands	Cords/Acre	% L	M	H1	H2	Dead	Dead+H2
Luce	12	18.2	64	12	14	6	4	10
Schoolcraft	2	18.8	59	16	12	6	8	14
Marquette	8	16.8	62	9	9	9	10	19
Averages		17.9	62	12	12	7	7	14

vulnerable intermediate/suppressed trees had a higher proportion of the cordwood volume in the Moderate, Heavy 2, and Dead damage categories. This held true for all three years of this study.

1993 Survey

Twenty-one stands were surveyed in Luce and Marquette Counties. Three hundred ninety-four plots representing 1,010 acres were measured (Table 5). The Luce County stands had also been damaged and surveyed in 1991 and in 1992. There was no defoliation in Luce County in 1993. The 1992 Marquette County stands reported above were in southeast Marquette County, and the 1993 stands in the southwest. The data for Luce and Marquette County are handled separately in the following tables and analysis. As reported in Table 5, the sites and defoliation histories are very different. The southwest Marquette County stands are unusually productive, and heavily stocked.

Mortality and damage are reported in Table 6. Current mortality averaged less than 2 cords/acre in both counties. The Heavy 2 (H2) category volume is added to current mortality to determine projected losses. Average projected losses (Dead + H2) in Marquette County are 7.8 cords/acre compared to 3.4 cords/acre in Luce County.

Marquette County had significantly higher proportions of total volume in the Heavy 1 (H1) and Heavy 2 (H2) categories (Table 7). However, the proportion of mortality to total volume was similar to Luce County's due to the greater stand volumes in Marquette County. Mortality ranged from 0.1 to 4.5 cords/acre in Luce County, and from 0.3 to 1.8 cords/acre in Marquette County. Projected losses ranged from 0.2 to 9.3 cords/acre (an average 17% of total volume) in Luce County and 5.3 to 11.9 (an average 21% of total volume) cords/acre in Marquette County.

Figure 2 shows a significant shift in damage category volumes from 1992 to 1993 in Luce County. After the second defoliation, there was 39% more volume in the Moderate damage category and 42% less in the Light category. A small proportion of the 1992 Heavy 1 category trees moved into the Heavy 2 category in 1993, and the Dead category doubled to 8%.

Summary

The overall impact of the jack pine budworm on the most heavily defoliated sites was variable. Several stands were identified for salvage and regeneration.

The average loss of 1.6 cords/acre or projected loss of 3.4 cords/acre after two years of defoliation in Luce and southeast Marquette Counties is

Table 5. Inventory Statistics Summarized by County and Project (1993 Survey).

County	Number of Stands	Number of Plots	Acres	Age	Site Index	Basal Area	Cords per Acre
Luce	14	313	638	64 ±7	50 ±4	94 ±19	21 ±6
Marquette	7	81	372	66 ±5	61 ±3	114 ±18	38 ±7
Totals	21	394	1,010				

Table 6. Cords/Acre per Damage Category Summarized by County and Project (1993 Survey).

County	Number of Stands	Cords/Acre Total	Living	L	M	H1	H2	Dead	Dead+H2
Luce	14	20.6	19.0	4.6	10.6	2.1	1.8	1.6	3.4
Marquette	7	37.5	36.3	0.6	21.8	7.3	6.6	1.2	7.8
Standard Error									
Luce		5.6	5.4	3.8	4.4	0.9	1.8	1.4	
Marquette		7.0	7.0	0.6	7.9	2.4	2.4	0.5	

Table 7. Damage Category Volumes as a Percentage of Total Volumes Summarized by County and Project. (1993 Survey).

County	Number of Stands	Cords/Acre	% L	M	H1	H2	Dead	Dead+H2
Luce	14	20.6	22	51	10	9	8	17
Marquette	7	37.5	2	58	19	18	3	21

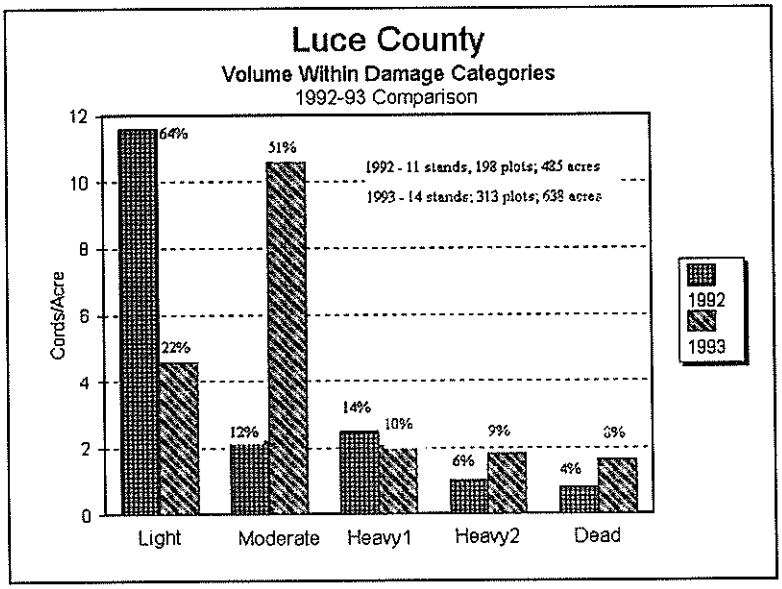


Figure 2. Change in Damage Category Volumes, Luce County, 1992 vs. 1993.

significant. This represents a loss of 8% of the stand volume, with the risk of loosing an additional 9% of the current volume if all H2 category trees die. The predictions of loss from year to year assumed population collapses the following year. This happened in 1993. We initially predicted a 99% volume loss over time in 1991. A 7.5% loss was realized in 1992, and additional impacts from the 1992 defoliation raised loss estimates to 14.4%. In 1993, estimates reached an average of 8%, with final projections at 17% if all H2 category trees died. The final figures will likely be in the 8 to 17% range with some apparently top-killed jack pine recovering.

The southwest Marquette County epidemic was unusually severe for a first-year defoliation. Current mortality was low at 1.2 cords/acre, or 3% of total volume. The unusually high proportion of trees in the H2 category, 6.6 cords/acre or 18% of total volume made this an extreme first-year epidemic. It is difficult to know until 1994 if many of the H2 category trees will have viable buds in the upper crowns. If so, these initial estimates will be reduced. However, these estimates will be affected by 1994 defoliation levels.

The budworm becomes epidemic in regular cycles of 8 to 12 years. The surveyed resource was an average of 65 years old. It had experienced one previous budworm outbreak after reaching harvest age. Losses can be greatly reduced and prevented by cutting and regenerating jack pine on a 50-year rotation. In economic terms, the return on the investment of growing jack pine for pulpwood is at risk to repeated jack pine budworm epidemics after the stand reaches 50 years of age. Younger, single-story, well-stocked stands are much less vulnerable to budworm-induced losses.

Aside from its value as pulpwood, jack pine is an important pioneer species. It will grow on poorer, drier, sandier sites unsuitable to red pine or white pine and may be important to wildlife. Kirtland's warblers, for example, prefer to nest in jack pine stands that are about 30 years old. Jack pine is considered a fire-dependent species--they have tightly closed cones that require high temperatures for opening. Thus, jack pines are adapted to relatively frequent disturbances in nature for their regeneration. Silvicultural practices which support the regeneration of young jack pine stands are not inconsistent with natural systems. Jack pines mature at about 60 years of age. A 50-year rotation would maintain younger, more vigorously growing stands that are more resistant to budworm attacks.

1991-93 Forest Health Conditions: Northern Lower Peninsula

Roger Mech, MDNR
Region II Forest Health Specialist

OPENING SUMMARY: REGION II

The winter of 1993-94 brought some welcome relief to the forests of Michigan's northern Lower Peninsula. Forest trees are enjoying an unexpected respite from the usual onslaught of forest insect pests this year, the result of record cold temperatures that blanketed the area this past winter. Extended periods of sub-zero cold were severe enough across much of the region to help keep the lid on some anticipated pest outbreaks, namely gypsy moth and jack pine budworm.

Heavy gypsy moth defoliation was limited to a few counties along Lake Michigan, where lake effects helped to moderate temperatures and to ensure the survival of gypsy moth egg masses.

Cold winter temperatures reduced the size of jack pine budworm populations despite fall surveys that had indicated they were on the increase. The cold weather was apparently severe enough to kill significant numbers of other forest insects, like the Saratoga spittlebug, a potentially serious pest of young red pine.

Still, certain forest health problems persist across northern Lower Michigan. Overmaturity, droughts in the late 1980's, and late spring freezes in the early 1990's have stressed forest trees, setting the stage for attack by wood borers and other pests.

Oak, in particular northern pin oak, continues to die at an increasing rate as age and other stresses take their toll. Fortunately, markets exist for salvaged wood, and progress is being made in managing oak forests to ensure the survival of young oak trees.

New tools are being used to aid our efforts to promote forest health. Aerial photography or "remote sensing" has helped to provide useful information about forest health cheaply and accurately. And computers and special computer programs called "Geographic Information Systems" are being used to provide detailed "health reports" of our young red pine and jack pine plantations.

GYPSY MOTH

Gypsy moth *(Lymantria dispar)* was first found in Michigan fifty years ago. Since then, a series of attempts have been made to curtail its spread, including several eradication programs during the 1950's, 60's, and 70's. Since the early 80's, the Michigan Department of Agriculture, the DNR, and other agencies have changed their approach to dealing with gypsy moth in the state. Instead of fighting to eliminate the insect, our efforts now focus on using methods to help reduce the effects of gypsy moth outbreaks. These methods include aerial applications of biological pesticides, improved forest management practices, and public education.

This change in strategy developed from the realization that gypsy moth is firmly established in Michigan, and that efforts to eliminate it cannot be justified environmentally or economically. Instead, gypsy moth populations on state forestland are watched closely and, when necessary, are suppressed using any of several mechanical, biological, and chemical management "tools." Often we choose to leave the suppression to viruses and other natural enemies while we regularly evaluate the need for additional control efforts during the season.

The exception to this rule occurs on high-use recreation areas. The Forest

Health Program annually treats several state parks and state forest campgrounds to reduce the nuisance caused by caterpillar feeding. A biological insecticide called B.t. is used because it is only toxic to leaf-eating caterpillars like gypsy moth. These areas are evaluated each year, and treatment is made only when outbreaks occur.

The DNR's emphasis in recent years has been to expand this "toolbox" of options for controlling gypsy moth outbreaks. Aerial photography and other "remote sensing" methods are now used extensively to provide precise information about the location and intensity of defoliation. Among other things, maps produced by these methods assist county gypsy moth coordinators in predicting where outbreaks are likely to occur in following years. Figures 1, 2, and 3 illustrate the extent of gypsy moth defoliation in Michigan for 1991, 1992 and 1993, respectively. Counties where gypsy moth activity was detected are highlighted in lighter grey. The dark spots within these counties indicate areas of significant defoliation.

Work has also begun developing a set of silvicultural guidelines for managing gypsy moth-susceptible forests in Michigan. The effects of defoliation on a woodlot are directly related to factors such as tree type, logging history, and geographic location, and forests are being broken into "habitat classifications" which consider these factors. Classifying a forest in such a way provides information about its growth potential, its susceptibility to drought and frost damage, and its suitability for wildlife. This information can then be used to evaluate various silvicultural options.

Satellite images taken in May of 1992 show the relationship between one of these factors, topography, and the susceptibility of an oak forest to frost

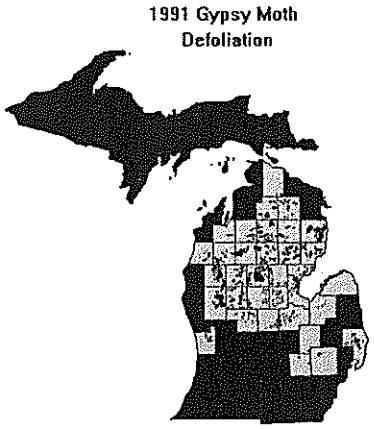


Figure 1. 1991 Michigan Gypsy Moth Defoliation

damage. These images show that the flat glacial outwash plains of the northcentral Lower Peninsula registered the coldest temperatures during the period. These are noted by the darker grey areas in Figure 4. Oak forests growing on these areas historically suffer more frequent spring frost damage than oak in surrounding areas. Oak forests that have been defoliated by frost are more likely to suffer long-term damage if defoliated by gypsy moth later in the season. This can be valuable information when evaluating the future of an oak forest on these sites.

The guidelines being developed for these various habitat classifications will take into consideration wildlife, timber, and recreation uses, and will take advantage of each habitat's full potential.

Much of the work being done involves the oak forest, which is particularly susceptible to attack by gypsy moth. The silvicultural guidelines are based on the premise that a healthy forest can readily defend itself against the stresses caused by gypsy moth defoliation. The primary goal is to encourage trees with strong, well-developed "crowns" or treetops, and healthy root systems capable of storing the energy needed for growth and maintenance. Strong root systems are particularly important for trees in the process of replacing leaves eaten by gypsy moth caterpillars. Smaller, weaker trees can use up their root reserves trying to replace missing leaves, and may not have the energy to fight off attack by other insects and diseases. Often these trees die.

Gypsy moth has many natural enemies, and efforts to establish them in Michigan are continuing. In particular, efforts to release the Japanese fungus *Entomophaga maimaiga* into forests where gypsy moth has been a problem have been encouraging, and a project to introduce a particularly effective predatory beetle, *Calasoma syncophanta*, is underway. While these biological controls will not single-handedly control gypsy moth outbreaks, they will become an important part of effective, environmentally sound gypsy moth management programs in Michigan.

Figure 2. 1992 Michigan Gypsy Moth Defoliation.

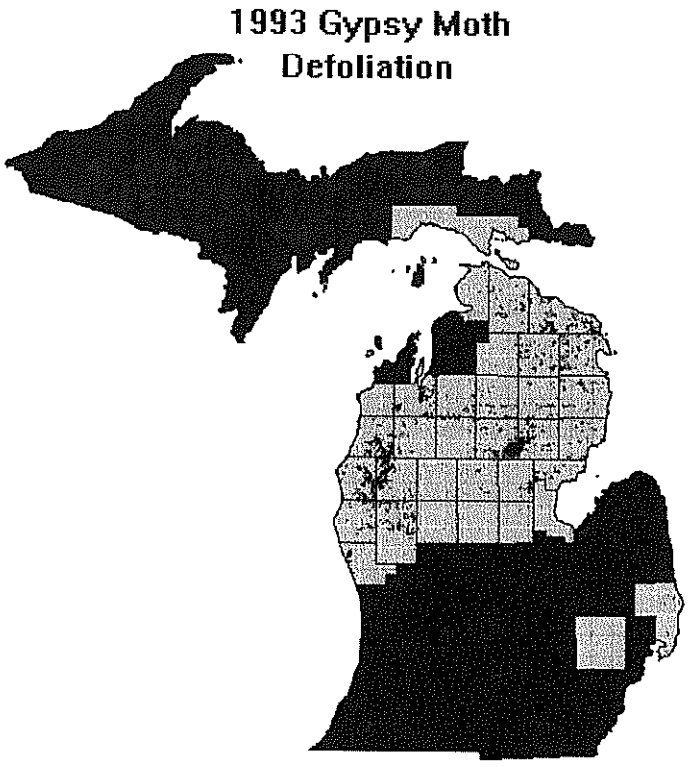


Figure 3. 1993 Michigan Gypsy Moth Defoliation

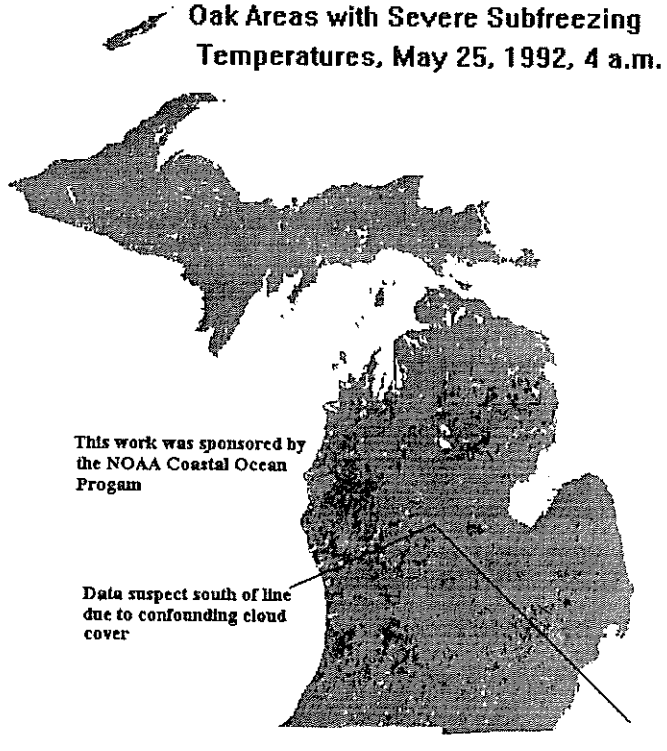

Oak Areas with Severe Subfreezing
Temperatures, May 25, 1992, 4 a.m.
This work was sponsored by the NOAA Coastal Ocean Progam
Data suspect south of line due to confounding cloud cover

Figure 4. Oak Areas with Severe Subfreezing Temperatures, May, 1992.

OAK MORTALITY

Introduction

Serious oak mortality began to occur in the northern Lower Peninsula about five years ago. Most of the serious dieback is occurring in the northern pin oak *(Quercus ellipsoidalis)* forests in the central part of the region. There are approximately 387,000 acres of this tree type, and mortality ranges from 10 to 100 percent across the range. Fortunately, markets for the dead wood have been good, with much of it being sold for fuelwood and as small sawlogs. The biggest question at this time is how to establish new oak seedlings that will replace the mature oaks being lost.

Oak and Susceptibility to Decline

The oak family in general, and northern pin oak in particular, are inherently susceptible to periodic bouts of decline and mortality. For one, oak is a **colonizer**--it is adapted to establishing itself in open areas under conditions of little or no shade, and does not compete well with more shade-tolerant species. Mature oak stands typically do not replace themselves in natural succession. Therefore, forest managers interested in keeping oak in the forest are often fighting a natural progression toward other species. This requires them to silviculturally create conditions favorable for reestablishment by oak species.

Northern pin oak is particularly prone to problems. It is found on glacial outwash, areas characterized by **shallow, droughty, nutrient-poor soils**. While genetically adapted to these sites, they are also more prone to periodic stresses caused by water table fluctuations and erosion. Poor growing conditions also lengthen the time northern pin oak needs to recover from bouts with stress.

Northern pin oak commonly regenerates from stump-sprouts. Only two or three sprouts typically survive to maturity, and **dead stems** can provide an entry point for wood decaying diseases like the butt rots. In addition, the ability of a tree to stump sprout is directly related to **root starch reserves**. Oak is at a particular disadvantage during bouts with defoliation and drought, when the amount of starch reserves available for storage in roots can be seriously reduced.

The History of Oak Decline in Michigan

Oak decline is nothing new to Michigan's forests. Since forest health specialists first began keeping good records in the 1950's, and probably for some time before that, large-scale oak decline has surfaced every decade. The stresses responsible for triggering the decline are varied and include oak leafroller and post oak locust outbreaks, spring frosts, and drought. Declines have varied in length from two to four years or more. Most have been isolated to the oak on poor sites, although good quality red oak has also been affected.

The Status of Oak Decline in Michigan

The current decline in northern pin oak first began to appear in the northern Lower Peninsula in the late 1980's. At present, mortality can be found in stands across its range. While much of the area is marked by 20 to 25 percent mortality, over 90 thousand acres are suffering 50 to 75 percent mortality, and many stands are completely dead.

The stresses currently plaguing northern pin oak are numerous, and include:

- the drought of 1987-88,
- two separate freezes during the spring of 1992,
- repeated gypsy moth defoliation (not all areas), and
- old age.

A Problem: Oak Growing on Pine Sites

The glacial outwash plains that are currently forested with northern pin oak were originally home to expansive stands of red and white pine. Extensive logging during the late 1800's and early 1900's sent most of the mature pine to sawmills, where it was converted to dimension lumber to meet an insatiable demand for building material across the region.

The logging slash left on site as operators moved through the area set the stage for extensive and repeated fires that often burned uncontrolled for weeks at a time. These fires encouraged an eventual site conversion to oak for two reasons:

- organic matter was removed from the soil surface, exposing the mineral soil and creating conditions favorable for acorn germination; and
- herbaceous and woody competition was eliminated without damaging the dormant oak buds found deep in the soil.

Oak gradually took over sites it was not particularly adapted to grow on, setting the stage for what has become somewhat predictable cycles of decline.

The Role of Secondary Pests

While drought, age, and defoliation set the stage for tree decline and mortality, they are not the ultimate causes of death. Trees do not die until they are killed by **secondary pests**, insects and diseases that "sense" stress and take advantage of the tree's weakened condition to establish themselves.

Healthy trees have natural defense mechanisms that help them ward off attack by these pests. The high moisture and low oxygen content of sapwood tissue is not favorable for the spread of rot fungi like *Armillaria*. Sapwood disrupted by lack of moisture during a drought is less likely to fend off attack by pathogens. Likewise, a tree's ability to physically isolate or compartmentalize fungi at the site of attack (e.g. a wound or hollow stem) is hampered by stress-induced changes in the tree.

Two-lined chestnut borer (TLCB) is also sensitive to a tree's ability to physically and biochemically defend itself from attack. Adult beetles lay eggs on the bark surface of stressed trees in springtime. These eggs hatch, and the young larvae move into the cambium tissue below the bark. Feeding by large larvae destroy the phloem (nutrient-conducting) and xylem (water-conducting) cells, cutting off movement of materials between roots and leaves. Depending on the speed and severity of the attack and the condition of the tree, death usually occurs within one to three growing seasons. Dieback occurs from the top down. Two-lined chestnut borer can be found in nearly all oak stands suffering mortality.

Two-lined chestnut borer is also a major factor in the **edge effect mortality** seen in many stands. Mortality is often confined initially to stand edges, especially those adjacent to clearcuts, roads or openings. More often then not, the effect is most noticeable along south-facing exposures. Among the reasons edges are more susceptible to decline are:

- There is an increased incidence of root rot fungi from stumps and roots of harvested trees.
- Higher soil temperatures in exposed areas can injure fine roots and mychorrhizae.
- Warm bark surfaces on exposed trunks provide attractive sites for egg laying by TLCB adults.

- TLCB is likely to be active in fresh-cut stumps and tops.
- Exposed trunks are more susceptible to sunscald damage.
- Felling and skidding wounds create stress in edge trees.
- There is an increased likelihood of radiation frost next to openings.

The Effect of Stress on Oak and Oak Regeneration

Trees differ in their ability to adapt to stress. Poplars, for example, will often shed leaves in response to drought, reducing the amount of leaf area available for transpiration. Oak, on the other hand, tends to "ignore" stressful conditions, and will usually attempt to set bud following a stressful growing season. The result can be:

- poor bud set the following spring, and/or
- increased epicormic branching.

Stress also reduces the stump-sprouting capability of northern pin oak. Trees forced to refoliate following defoliation from freeze or insect damage rely on root starch reserves for the energy needed. This depletes the amount of energy available for sprouting. How severe the effect will be depends on the severity and duration of the stressing agent, and the age and health of the tree. Older trees growing on poor sites and subject to repeated defoliations are most likely to lose stump-sprouting capability.

Stump sprouts are also susceptible to problems, including:

- attack by rot fungi that enter through dead stems,
- increased incidence of sunscald from exposure, and
- increased incidence of attack by insects (e.g. gouty oak gall) attracted to sun-warmed shoots.

Dealing with Decline and Two-Lined Chestnut Borer

When TLCB strikes a stand, the immediate management objective should be to reduce mortality. This can be done by promoting **stand vigor**. Unfortunately, only a few options are open to managers when TLCB outbreaks occur. These options fall under three broad categories:

- sanitation,
- salvage, and/or
- sitting tight.

Sanitation

Sanitation is the best option if the TLCB infestation is related to localized events that wound trees or reduce vigor. These wounding events typically occur as a result of:

- wind shears,
- flooding, and/or
- logging damage.

The primary objective of any sanitation effort should be to remove dead trees and those with advanced crown dieback. Usually, northern pin oak trees with more than 50 percent of the crown dead will die within one year and should be removed. Harvests are best done on frozen ground to reduce root damage to remaining trees. If possible, sanitation cuts should not be scheduled until the year following the disturbance to give the residual stand time to recover. Heavily stressed trees need at least a year to rebuild root reserves before attempting to fill crown gaps left by a cutting operation. For this reason, every effort should be made to minimize logging wounds during a sanitation cut.

Salvage

Salvage may be the best option if a merchantable sale can be made from dead oak and oak with advance crown dieback. Some general guidelines include:

- Mark trees when leaves are on to help assess crown condition.
- Salvage during the winter following a "normal" growing season.
- Avoid areas of the stand untouched or lightly damaged by TLCB.

Sitting Tight

Doing nothing may be the best option during statewide or region-wide outbreaks when further disturbances could prolong outbreak conditions. Following a drought, cuttings should not be scheduled until the winter following a growing season with adequate rainfall. In the case of heavy gypsy moth defoliation, cuts should be postponed until the winter following a population collapse. Depending on the severity of the disturbance and the crown condition within the stand, trees may still be vulnerable to mortality three to five years after stress conditions subside.

In the case of red oak stands where uneven-aged management is the objective, thinning should be avoided during a TLCB outbreak when:

- a reduction in stocking will increase the effects of wind on drought stress,
- mechanical damage to roots and main stems is likely, and
- roots and crowns are too weak to occupy spaces created by thinning

Things to Remember:

- Fresh stumps and roots created by thinning can favor root rot development.
- Trees usually die over a two- to four-year period.
- Infested trees cut within one year of infestation will contain TLCB larvae (summer cut) or adults (winter/early spring cut).

MINOR PEST PROBLEMS: REGION II

Michigan's Northern Lower Peninsula

1991 - 1993

PEST PROBLEM	TREE SPECIES	COMMENTS
Anthracnose (several genera)	Various Hardwoods	Common during cool, wet springs.
Birch Decline	White Birch	Increasing mortality across the birch type.
Cherry Scallop Shell Moth *(Hydria prunivorata)*	Cherry	Primarily a pest of pin cherry. Outbreaks last 1 to 2 years.
Chestnut Blight *(Endothia parasitica)*	American Chestnut	Present locally in isolated stands.
White-Tailed Deer *(Odocoileus virginianus)*	Various Species	Locally serious in young oak, aspen, and northern hardwoods.
Eastern Tent Caterpillar *(Malacosoma americanum)*	Cherry	Populations declining across the region.
Forest Tent Caterpillar *(Malacosoma disstria)*	Oak Maple Aspen	Heavy in '91; declining in '92.
Oak Wilt *(Ceratocystis fagacearum)*	Oak	Isolated centers in red oak stands in central and western parts of region.
Orangestriped Oakworm *(Anisota senatoria)*	Oak	Heavy in '91 in southcentral part of region.
Pine Shoot Beetle *(Tomicus piniperda)*	Scotch Pine	Confirmed in southern part of region. Questionable biological importance.
White Pine Weevil *(Pissodes strobi)*	White Pine	Throughout range of white pine in region.

PLANTATION STOCKING AND SURVIVAL

Since the early 1980's, tree stocking levels in young **jack pine** *(Pinus banksiana)* and **red pine** *(Pinus resinosa)* plantations in the northern Lower Peninsula have been monitored by members of the Region II Forest Health Program. Each year plantations one, three, and five years of age are surveyed for growth and survival. Plantations are also looked at to determine whether competing vegetation is affecting growth and survival of the young trees. This three-step review provides a means of evaluating tree performance, and provides an index for estimating the ability of a particular site to support either **jack pine** or **red pine**. The information is used by timber management specialists to assist them in matching species to specific site conditions, and to help pinpoint problems related to tree-handling and planting methods.

Pest scouts review planting completion maps to determine plantation layout and orientation. Plantations are then reviewed in the field to determine whether any variations exist between the maps and the actual planting. For example, areas of dense aspen regeneration that have become established since the site was cut may be left unplanted. Pest scouts record these changes in the plantation table of the forest health database.

Fixed-radius circular plots are distributed throughout the plantation and the number of trees within each plot is recorded. Tree height is also recorded. Plot spacing is determined by calculating the number of plots necessary to provide approximately a five percent sample. Once a plot grid is established, plot locations may be modified to avoid taking samples in areas that might bias the estimate. For example, plots are shifted to avoid logging roads and areas that have been furrowed but not planted. However, areas within the plantation that were not planted because of heavy logging slash would be included in the survey.

Some interesting trends are evident in the following stocking charts. Figure 1 shows that the average stocking of **jack pine** trees one, three, and five years of age has remained relatively constant during the past ten years at about 575 trees per acre. Figure 2 indicates that the average stocking of one-, three-, and five-year-old **red pine** is about 550 trees per acre. **Jack pine** is planted at a rate of approximately 1200 trees per acre, indicating that, on average, stocking decreases by half during the first five years. **Red pine** is planted at a rate of about 900 trees per acre, and stocking decreases on average about 40 percent

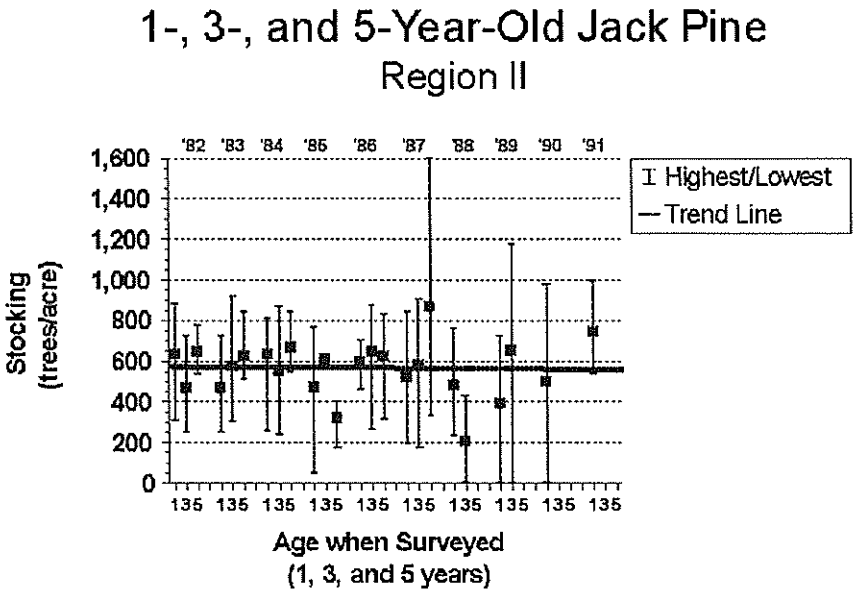


Figure 1. Average Stocking of Jack Pines at One, Three, and Five Years of Age.

during the first five years. The actual number of trees planted may be somewhat lower depending on terrain, number and location of stumps, and the site location and layout.

Do these numbers reflect a typical pine plantation in northern Lower Michigan? Probably not. Several other factors must be considered when summarizing the history of plantation stocking in Region II.

A number of changes have been made in the planting program in the past ten years in an effort to improve tree survival. Some of the major improvements include:

- use of refrigerated vans to transport trees from nursery to the field;
- more efficient handling to reduce the time trees are out of the ground;
- on-site sorting to eliminate poor quality trees;
- root pruning prior to machine planting trees to encourage quicker root growth after planting;
- root soaking trees prior to machine planting;
- training of planting crews and contract supervisors on proper tree handling and planting procedures;
- use of two-year-old **red pine** and **jack pine** seedlings instead of three-year-old to maximize root:shoot ratio and to reduce risk of winter top-burn; and
- increased use of containerized seedlings. Preliminary data suggests that high initial costs are offset by significantly better survival. This is particularly true with fall plantings of containerized seedlings, where 95% of trees are still alive after one season.

A comparison of tree stocking by age helps clarify the role of improved handling techniques in determining planting success. Figures 3, 4, and 5 summarize the average stockings of jack pine and red pine over the past ten years at ages one, three, and five, respectively. For one-year-old **jack pine** (Figure 3a), there was an average increase in stocking of 50 trees per acre over the past ten years. For **red pine** (Figure 3b), the increase was even greater, averaging about 150 trees per acre.

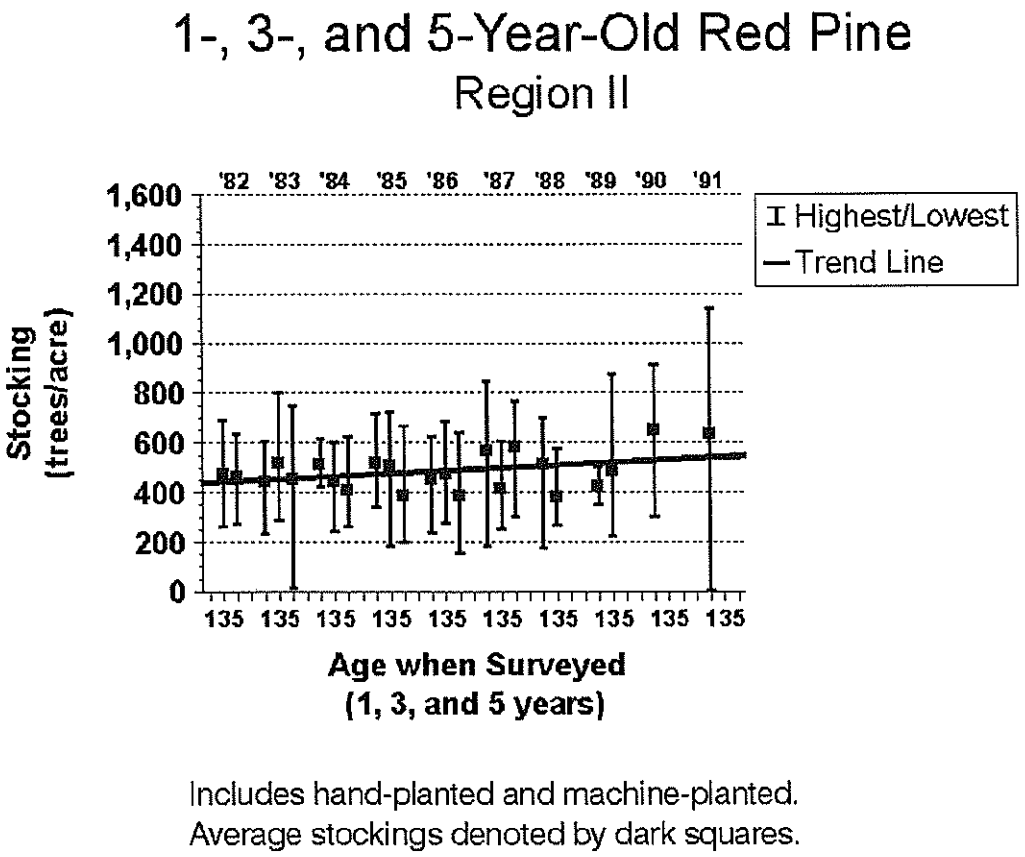


Figure 2. Average Stocking of Red Pine at One, Three, and Five Years of Age.

For three-year-old **jack pine** (Figure 4a), the average number of trees per acre has remained nearly constant over the past ten years. Three-year-old **red pine** has also remained constant, despite improvements in tree handling techniques.

At five years of age (Figure 5a), the average stocking of **jack pine** trees increased again over the ten-year period by about 125 trees per acre. An improvement was also evident in five-year-old **red pine** plantations (Figure 5b), which increased in stocking by an average of 50 trees per acre.

In years one and five, the advantages of better tree handling methods can be seen in the steady increase in average tree stocking over the past ten years.

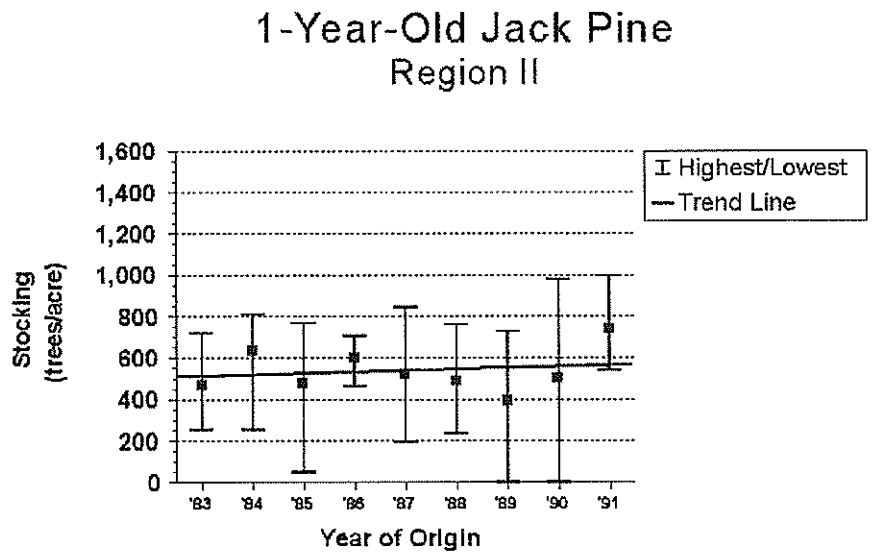


Figure 3a. Average Stocking for One-Year-Old Jack Pine.

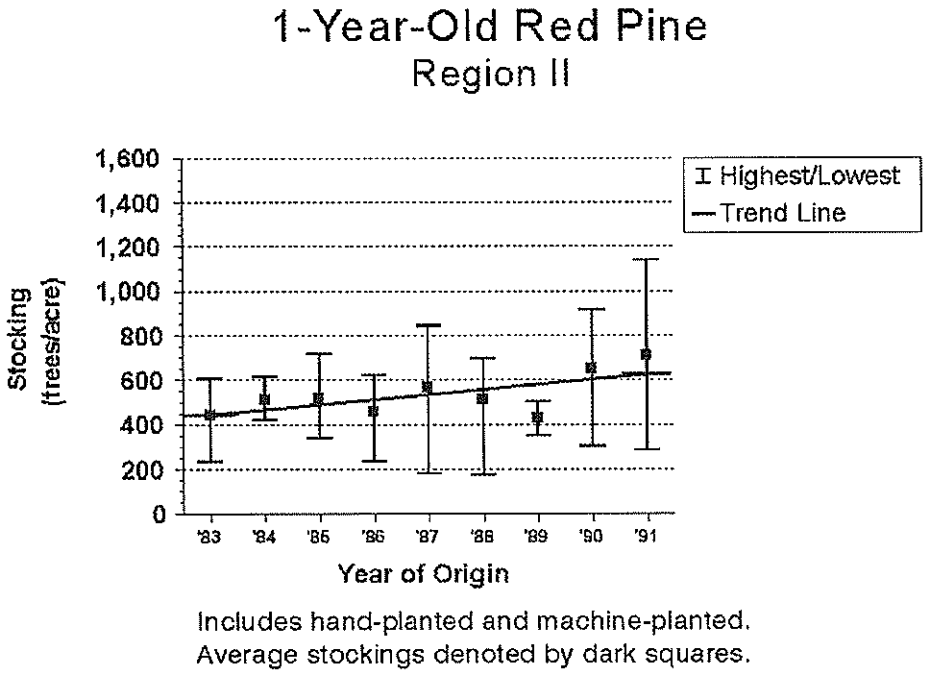


Figure 3b. Average Stocking for One-Year-Old Red Pine.

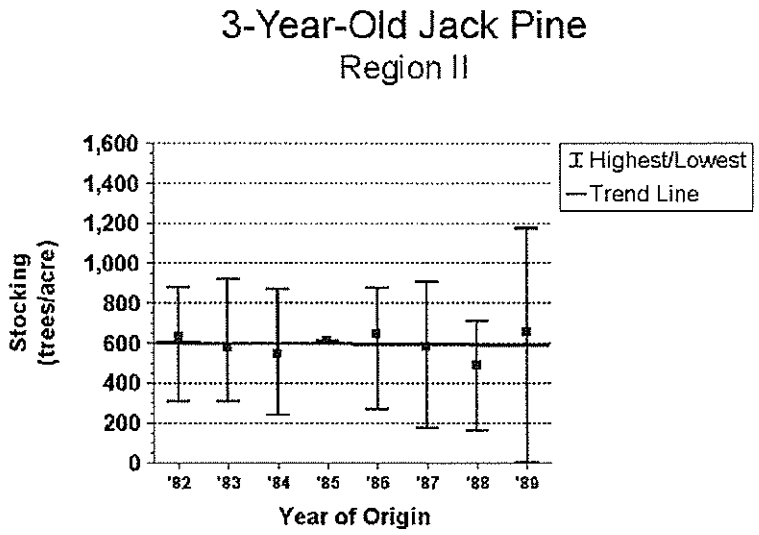


Figure 4a. Average Stocking for Three-Year-Old Jack Pine.

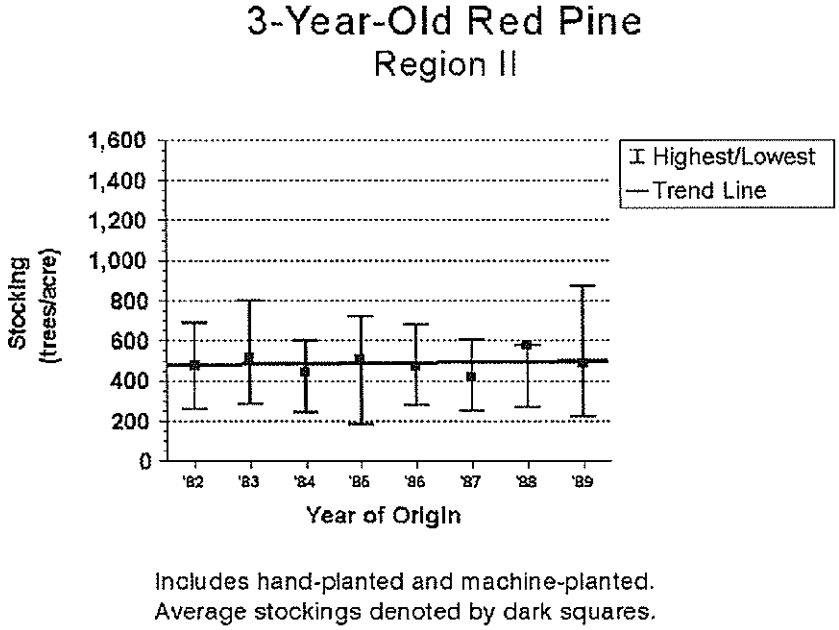


Figure 4b. Average Stocking for Three-Year-Old Red Pine.

In year three, however, it appears other factors may be offsetting these positive effects. One of these factors may be competition from herbaceous and woody-stem plants during this early establishment period.

During the first year or two following planting, weed and hardwood brush may not have fully recovered from the mechanical disturbance caused by trenching during site preparation. Young seedlings are subject to less stress from competition and can get a "jump" in growth during this period.

By year three, hardwood brush and herbaceous weeds have recovered, and many pine seedlings are not yet tall enough to escape some

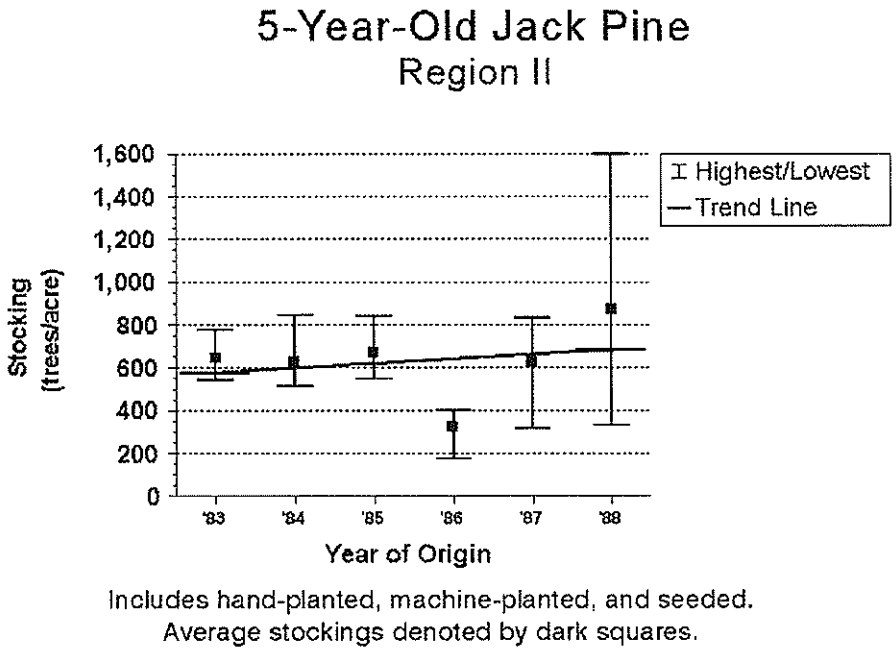


Figure 5a. Average Stocking of Five-Year-Old Jack Pine.

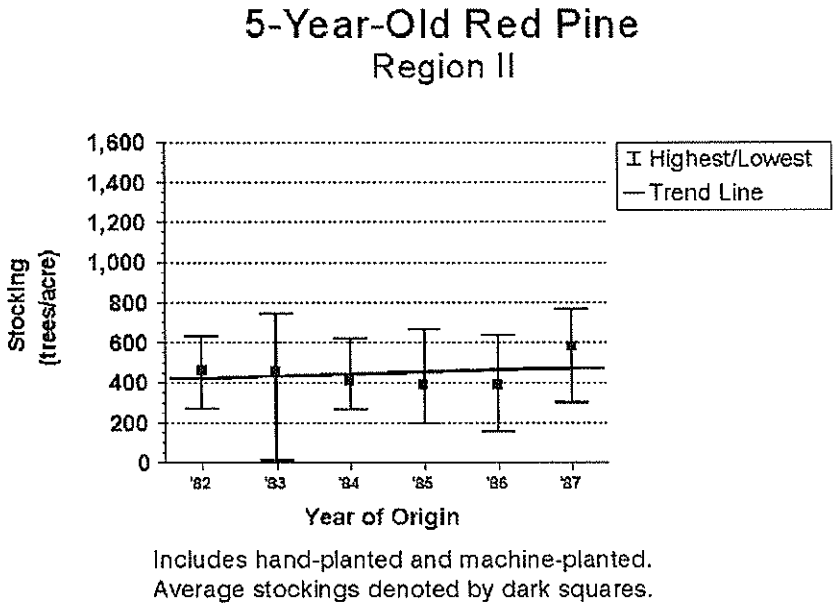


Figure 5b. Average Stocking of Five-Year-Old Red Pine.

overtopping effect from the competition. In addition, root systems on many of the young trees are not yet developed enough to compete with those of nearby broadleaf weeds and hardwood brush. This effect can be particularly noticeable on the dry, sandy soils typical of many Region II planting sites.

By the time the trees are five years old, height and root development is often adequate to allow them to compete more favorably with hardwood competition. In many cases, survivability and vigor as determined at the time of tree planting again becomes the limiting factor.

Figure 6 compares the performance of hand- and machine-planted trees in Region II during the past ten years. Machine planting appears to have the edge over hand planting for both red and jack pine. One explanation may be that machine planting involves less handling and may be less stressful to bare-root seedlings, which make up the majority of planting stock used in Region II.

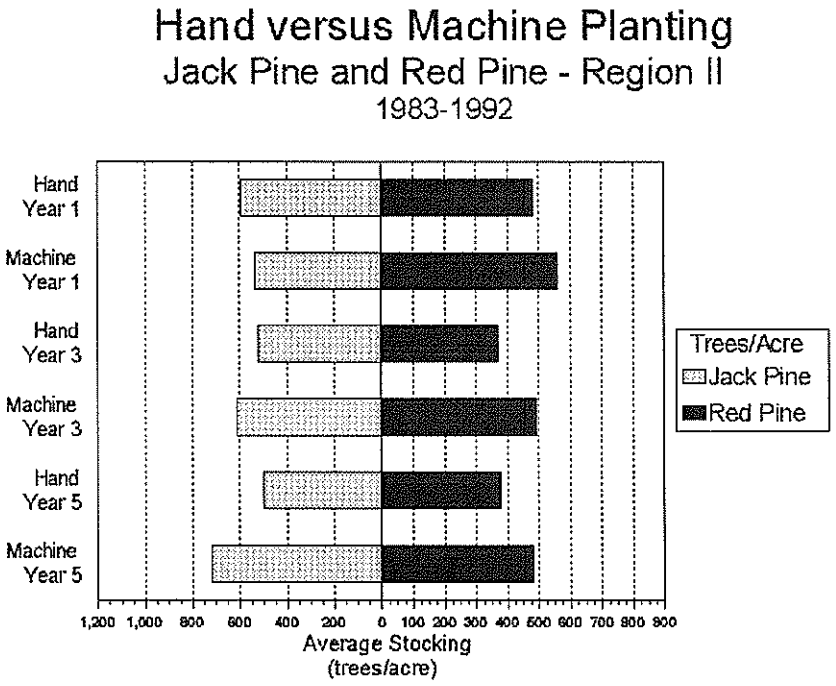


Figure 6. Hand Versus Machine Planting, Jack Pine and Red Pine, Region II.

1991-93 Gypsy Moth in Michigan

EFFECTS OF TREE SPECIES AND SITES ON SURVIVAL AND GROWTH OF THE GYPSY MOTH

J. A. Witter (U of M), C. A. Chilcote (MSU), J. L. Stoyenoff (U of M), and M. E. Montgomery (USDA-FS)

We studied the effects of various tree species and sites on gypsy moth performance throughout the Lower Peninsula of Michigan from 1987 to 1992. Major results from the six-year field study are as follows: 1) Gypsy moth survival and growth varied considerably by year, site, tree species, and tree phenology. 2) The relative suitability of several common Great Lakes area hosts varied considerably, both among species normally thought of as preferred and nonpreferred and among those species considered preferred. A diet of northern pin oak, trembling aspen, or paper birch all lead to great survival, high pupal weight, and short development times. However, larvae feeding on nonpreferred hosts such as boxelder and pignut hickory had poor survival, long development times, and low pupal weights. Suitability of other species was variable, often due to the effects of temporal, physical, or chemical barriers present on these species. 3) Variation in tree phenology occurred throughout the season, both among and within tree species, sites, environmental stress conditions, and regions. 4) Red oak and trembling aspen had significantly faster leaf development than northern pin oak, white oak, or bigtooth aspen. 5) Phenological development on individual trees showed a strong year-to-year correlation. 6) Phenological development of overstory trees was significantly faster than phenological development of understory trees. 7) Interclonal variation in phenology of bigtooth aspen and trembling aspen was high, while intraclonal variation was low. These differences in leaf phenology led to a window of vulnerability existing for each clone. While insects that initiated feeding on phenologically delayed clones had poorer survival and lower growth rates than did larvae that initiated feeding on phenologically more advanced clones, later in the season these larvae were able to catch up as the phenology of delayed clones caught up to that of more advanced clones. Because of this, pupal weights did not show significant effects of clones. 8) Heaviest pupae normally were reared on the two aspen species. 9) Drought had a major effect on pupal weights.

Management implications of the work to date include:

- **Outbreaks occur in oak, oak-aspen, and aspen stands.**

From 1983 to 1989, outbreaks of the gypsy moth were very common in oak and oak-aspen stands. Outbreaks started in the Midland, Michigan area and now are common as far north as Cheboygan, Michigan. Recently, we have seen separate outbreaks on good aspen stands in central and northern lower Michigan, as well as continued outbreaks in oak and oak-aspen stands. Data from the 1987 to 1992 sleeve cage studies confirm that gypsy moth pupae can reach very large sizes on both trembling aspens and bigtooth aspens if the tree phenology is appropriate.

- **Outbreaks can occur in pure aspen stands if stands contain some clones that are flushing at the time of early larval dispersal.**

At the beginning of this study in 1987, the senior author would have argued that it was impossible for a gypsy moth population to reach outbreak numbers in a nearly pure aspen stand. This was based on the fact that both trembling aspen and bigtooth aspen can exhibit as much as a four- to six-week variation among clones in the date of budbreak. The great variation in aspen clone phenology made it seem improbable

that there would be much larval survival. The data from the 1988 and 1989 aspen clone studies showed that this was not correct. Unless the phenological mismatch between host and insect is very severe, many gypsy moth larvae will survive, and gypsy moth larvae that have delayed development due to poor match with phenology can recover and attain pupal weights equal to those reared on early flushing clones. If the mismatch is severe, however, there will likely be high larval mortality.

- **Stands with a high percentage of preferred hosts in the overstory and understory are more vulnerable to damage.**

Outbreaks in the northeastern U.S. rarely occur in stands dominated by non-preferred host species. In the New England area, susceptible stands that have a long history of gypsy moth defoliation are characterized by having preferred hosts, sandy soils, or ridge locations, and often have a history of ecological disturbance. In Michigan, most defoliation to date has occurred in oak and oak-aspen stands. After five years of gypsy moth outbreaks in the Midland, Michigan area, 13% and 3% of all trees greater than six inches DBH (diameter-at-breast height) in the control and treatment blocks had died respectively (Kroll, pers. comm. 1990). An oak mortality survey conducted by the Michigan DNR in 1991 showed at least 100,000 acres of oak mortality from the gypsy moth and drought in eight counties (Sapio, pers. comm. 1991).

- **Tree phenology may have a major effect on gypsy moth survival and growth.**

Early larval survival showed considerable variation on bigtooth aspen and trembling aspen due to phenological differences between aspen clones. In an extreme situation, mismatch between hosts and insects on bigtooth aspen clones resulted in 100% larval mortality. Phenological development of most tree species is greatly delayed on frost-prone sites and mismatches between larvae and hosts will probably lead to poor survival on these sites.

- **Managers should consider flushing times of susceptible host species more carefully when determining spray application dates.**

Land managers involved in gypsy moth suppression programs in the Lake States region need to schedule spraying operations more carefully so that timing of treatment better matches the phenology of trees in the spray block. Additional research in the Lake States is needed to better understand the relationship between flushing times of preferred tree species and spray efficacy when using *Bacillus thuringiensis*. There may be a phenological window when spraying will maximize canopy penetration and leaf contact.

- **Understory vegetation may play a major role in making some stands more susceptible to the gypsy moth.**

Ticehurst and Yendol (1989) reported that most early instar gypsy moth larvae occurred in the lower canopy, understory, and forest floor in mixed oak forests with moderate to dense gypsy moth populations. Our observations in Michigan support their findings. Young gypsy moth larvae often are extremely common in oak and oak-aspen stands on the following understory species: witch-hazel, serviceberry, and young regenerating oaks and aspens.

- **Stands in which foresters are intensively managing the understory for oak regeneration may be extremely vulnerable to damage.**

It is often difficult to obtain sufficient regeneration following a timber harvest in red oak stands in Michigan. Both the shelterwood and clearcut methods are used for regenerating oak in the Lake States region. Harvested stands often have inadequate advanced oak regeneration to adequately replace themselves. Land managers in Michigan are intensively managing oak regeneration in some areas. They need to understand that some of these regenerating stands may be vulnerable to damage from the gypsy moth.

- **Economically important oak regeneration sites need to be carefully monitored and protected.**

Intensively managed oak regeneration sites must be monitored annually if a gypsy moth outbreak is occurring in the area. It may be necessary to occasionally spray these sites with *Bacillus thuringiensis* to protect the young oaks from defoliation by the gypsy moth.

THE EFFECTS OF VARIOUS DIET SEQUENCES ON GYPSY MOTH REARED UNDER FIELD CONDITIONS IN MICHIGAN

J.L. Stoyenoff (U of M), J.A. Witter (U of M), M.E. Montgomery (USDA-FS), and C.A. Chilcote (MSU)

The effects of various diet sequences on the performance of the gypsy moth (*Lymantria dispar* (L.)) were studied when this insect was reared from hatch to pupation on intact host trees in the field. The effects of diet sequences are of interest because a large proportion of gypsy moths likely experience multiple hosts during their lives, due to host switching that occurs naturally in the field. The tree species used for this study were red oak (*Quercus rubra* L.), white oak (*Q. alba* L.), bigtooth aspen (*Populus grandidentata* Michaux), and trembling aspen (*P. tremuloides* Michaux). These are commonly available hosts in the Lake States region. The study spanned two years and was performed at two different field sites in central Michigan.

Conclusions drawn from this study include: (1) Different multiple host diets composed of favorable species have very different effects on gypsy moth performance, ranging from very good to poor. (2) Larvae that spent their first two weeks feeding on red oak were ahead of larvae on all other host species in terms of mean weight, mean relative growth rate (RGR), and mean larval development, while larvae on bigtooth aspen were ranked behind all others in terms of mean weight, RGR, and development. (3) Combination diets did not seem to be inherently better or worse than diets composed of only a single species; rather, larval performance was impacted by the types of host species eaten and the time during the larval season that these species were consumed instead of whether or not larvae ate single species diets or mixed species diets. (4) Various measures of gypsy moth performance were impacted by the two elements in a diet sequence to different extents in the latter part of the season; larval weights, RGRs, and development rates show continued effects of the first host fed upon while mortality and pupal weights were impacted strongly by the second host type eaten. (5) Of the diet combinations investigated in this study, an early diet of red oak followed by later feeding on an aspen, particularly trembling aspen, was of the most benefit to larvae in terms of attaining high levels of fitness. Despite increased levels of larval mortality on trembling aspen, the proportion of insects dying on this host was overall low enough to make aspen-ended diets a good risk, since the fecundity that results from late-season feeding on this species is greatly elevated.

MICHIGAN GYPSY MOTH IMPACT MONITORING SYSTEM (MIMS)

J. Witter (U of M), J. Stoyenoff (U of M), B. Leutscher (U of M), F. Sapio (MDNR), and R. Mech (MDNR)

During the last ten years, there have been several kinds of major disturbances that have occurred in oak, aspen, and northern hardwood stands throughout the Lower Peninsula of Michigan. Defoliation by the gypsy moth became a major disturbance in Michigan forests during the 1980's and remains a problem at present. In addition to insect damage, Michigan's hardwood forests also face stress from severe droughts, such as the the hundred-year drought event of 1988. Frost stress plays a role as well, particularly in low-lying areas. Frost stress can occur on a yearly basis at some locations due to physiographic factors; in addition, severe frost events can take place on a region-wide basis, such as the severe frost events in the spring of 1992.

Before 1990, land managers were reporting very low levels of tree mortality in Michigan's hardwood stands. However, oak mortality surveys conducted by the DNR in 1990 and 1991 found 30,000 and 100,000 acres of oak mortality respectively, likely due to interactions of gypsy moth defoliation and/or drought stress. Other than these two surveys, little systematic information has been available on forest health in Michigan's hardwood stands. Therefore, a system of plots to monitor forest health in the hardwood forests of Michigan's Lower Peninsula was established in 1990 with funding from the Michigan DNR, the U.S. Forest Service, and the University of Michigan.

The objectives of the work are: 1) establish an impact plot system in Michigan to monitor forest health; 2) survey and monitor over time tree mortality and conditions of oak, aspen and northern hardwood stands; 3) survey regeneration in oak, aspen, and northern hardwood stands; 4) determine efficacy of various types of aerial photography for monitoring forest health; 5) develop a multifactor ecological site classification system for plots in MIMS; 6) determine relationships among tree mortality, stress history, and stand, site, and soil variables; 7) determine the effects of silvicultural treatments on the health of stands in MIMS; and 8) develop and validate a rating system that can be used by managers to rate potentially vulnerable stands.

To meet these objectives, the following work will be done from 1991-1999: 1) establish 568 plots in 284 stands throughout lower Michigan (1991-1993); 2) collect an initial data base from this plot system (1991-1993); 3) sample regeneration in all plots and intensively sample regeneration in the oak forest type (1991-1995); 4) evaluate use of aerial photography techniques to measure various forest health parameters (1993-1994); 5) remeasure all plots in system (1994-1995, 1997-1998); 6) evaluate the effects of various types of silvicultural treatments on forest health using pair stands (treated and untreated) (1994-1996); 7) develop a multifactor ecological site classification system through analysis of vegetation, soils, physiography, and climate (1995-1997); 8) determine relationships among forest conditions, stress factors, and stand, site, and soil variables (1995-1998); and 9) develop and validate a model for use by foresters to rate potentially susceptible stands (1997-1999).

The MIMS system consists of 568 plots located in 284 stands throughout 34 counties in lower Michigan. Of these 198 are oak stands, 48 are aspen stands, and 38 are northern hardwood stands. In each study stand, we have established two 100 x 100 ft. plots in which we record data at the level of the individual tree for all trees greater than 2.0 inch DBH (diameter-at-breast height). Data collected include tree species, DBH, crown position, and tree condition (live or dead). Additionally, intensive data collection is performed for the first 15-20 trees/plot to obtain information on tree height, live crown height, crown condition (vigor), and current defoliation. Two 30 x 30 ft. subplots are also established with each of the large plots. In these subplots, we have tallied all wood regeneration in two size classes (0-1.0 inch DBH, 1.1-2.0 inch DBH) and five species classes (maples, oaks, aspens, conifers, other hardwoods). More intensive sampling involving a larger number of subplots, a finer scale based on stem height, and identification of stems at the species level is currently being carried out in MIMS oak stands throughout the central part of the Lower Peninsula.

Results to date have shown that overall the health of Michigan's forests is quite good (e.g., oak forest type: 104 sq. ft./acre of basal area and 4% dead; aspen forest type: 117 sq. ft./acre and 4% dead; northern hardwood forest type: 121 sq. ft./acre and 1.7% dead). However, there is much variation in response to stress factors occurring among individual stands and ecosystem units within each forest type. For example, there is a range of 0-50% overstory trees standing dead among MIMS stands in the oak forest type. Additionally, within each forest type there is considerable variation in mortality among the various major tree species. Fore example, in the oak forest type there is 19% mortality of northern pin oak, 11% mortality of white oak, 7% mortality of red oak, and 5% mortality of red maple, As well, there is considerable variation in forest composition and forest health among counties in Michigan.

In general, there are few dead stems in the dominant and codominant crown classes of aspen and northern hardwood forest types. This is also true for the oak forest type, except for northern pin oak in dry oak ecosystems. In all forest types, tree mortality is generally much higher in the intermediate and suppressed crown classes. Tree vigor of the living trees is good throughout all forest types, except for oak trees in the suppressed crown class in oak stands.

Regeneration is adequate in the northern hardwood forest type, and shade-tolerant species are replacing themselves as expected. In both aspen and oak stands, the species showing the best regeneration is red maple. In oak stands, the amount of regeneration is somewhat low in the smaller size class (mean of 100±21 stems/acre in the 0-1.0 inch DBH class) and is very poor in the larger size class (mean of 8±3 stems/acre in the 1.1-2.0 inch DBH class).

The MIMS stands that were established in 1991 were revisited in 1992 and 1993 as well to collect data on changes in conditions in the plots. These data have shown that overstory oak mortality has increased over the last three years, particularly that of northern pin oak (9% to 36% mortality). Red oak mortality has increased over the past three years from 4% to 8% in the oak forest type.

RESEARCH ON THE IMPACT OF GYPSY MOTH ON ASPEN IN MICHIGAN

ANNUAL REPORT FOR 1993

John H. Hart (MSU)

OBJECTIVES

The objectives of this project were to determine how defoliation caused by gypsy moths predisposes aspen to secondary lethal organisms, specifically:

1) to compare the reaction of two congeners (bigtooth and quaking aspen) to defoliation stress and subsequent disease susceptibility;

2) to determine if gypsy moths prefer to feed on aspen with low vigor.

PREVIOUS WORK

In 1986 pilot studies were initiated to determine the effects of gypsy moth defoliation on bigtooth and quaking aspen in Michigan. Six areas of mixed northern hardwoods of approximately 20 acres each were selected in Midland County (an area of high defoliation in 1986). Three areas were sprayed with *Bacillus thuringiensis* (1986-1988) and three were designated as control areas. In late June all aspen within twenty-five 10-factor prism plots were examined in each of the six test areas. Species, diameter at breast height (DBH), percent defoliation, and condition were recorded for each tree (75 bigtooth and 113 quaking aspen). The occurrence of secondary fungi and insects was recorded 1986-1993.

Data on 228 additional quaking (58) and bigtooth (170) aspen in fifteen 0.02 hectare plots in Osceola County were collected in 1989 on aspen that had not yet been defoliated prior to 1989. Twenty 0.02 hectare plots (10 each for quaking and bigtooth aspen) were established at Rose Lake Wildlife Research Area in 1990. No gypsy moth defoliation has occurred on the Rose Lake trees. For all plots the condition and size of each aspen stem (permanently marked) were recorded. The size and species of all trees other than aspen were also determined. The cause of aspen stem mortality, the occurrence of potentially lethal pathogens and insects on live stems, and the amount of defoliation were recorded.

In 1993, the amount of defoliation (the percent of foliage stripped from each tree as estimated ocularly to the nearest 10 percent) was determined for all plots between June 22-28 (the time of maximum defoliation and minimum refoliation).

RESULTS

1. Defoliation in 1993 was low in all plots, (Tables 1, 2, and 3).

2. Prior to 1993 when defoliation by gypsy moth exceeded 10 percent, quaking aspen was always more heavily defoliated than bigtooth aspen. In 1993 in Osceola County, defoliation of bigtooth aspen (17.2 percent) significantly exceeded defoliation observed on quaking aspen (3.3 percent). See Table 2.

3. In Midland County a very high level of defoliation (1986) was followed by two years with little defoliation (1987, 1988) and a marked increase in defoliation three years later (1989). A similar pattern was observed in Osceola County except that defoliation has remained low for four years and has not yet shown a second peak.

Table 1. Mortality and Defoliation (%) of Aspen in Midland County, Michigan, 1986 to 1993.

	Species	1986	1987	1988	1989	1990	1991	1992	1993
Defoliation (%)	Quaking	84	4.3	10.4	44.2	26.0	48.3	2.0	1.0
	Bigtooth	54	1.9	5.1	18.5	17.2	10.1	0.4	1.3
Mortality* (%)	Quaking		7.1	7.6	10.3	22.9	11.6	13.6	11.8
	Bigtooth		2.7	1.3	6.9	4.5	3.1	3.2	0

*Mortality is measured from June to June of the following year.

4. At all three study sites the mortality of quaking aspen stems has been three to five times the rate of mortality of bigtooth aspen.

5. Although there has been very minimal defoliation of any of the aspen at Rose Lake (none of it caused by gypsy moth), the quaking aspen have died at about the same rate as in areas with gypsy moth defoliation. A number of quaking aspen clones in southern Michigan are experiencing a high rate of mortality (20 percent in two years at Rose Lake) from an unknown cause.

6. The root-rotting fungus, *Armillaria, spp.* was observed on 90 percent of the dead or dying stems.

This study will continue to follow the fate of 740 aspen stems in three locations in Michigan. At the end of 1993, 544 of the trees are still alive. They will be surveyed in late June or early July for defoliation, mortality, and occurrence of secondary lethal organisms.

Apparently gypsy moth is cycling at different rates in Midland and Osceola counties, at least on aspen. Peak years of defoliation in Midland County were in 1986, 1989, and 1991 (Table 1). For Osceola County, the only recorded peak year was in 1989. Since then, defoliation levels in Osceola County have remained low.

Table 2. Mortality and Defoliation (%) of Aspen in Osceola County, Michigan, 1989 - 1993.

	Species	1989	1990	1991	1992	1993
Defoliation (%)	Quaking	88	5.6	2.5	1.4	3.3
	Bigtooth	43	4.1	3.5	2.5	17.2
Mortality* (%)	Quaking		6.9	13.0	8.5	4.7
	Bigtooth	11.6**	4.2	4.9	5.8	0.7

*Mortality is measured from June to June of the following year.
**Total for both species of aspen

Table 3. Mortality and Defoliation (%) of Aspen at Rose Lake, Michigan, 1990-1993.

	Species	1990	1991	1992	1993
Defoliation (%)	Quaking	0	0	2.6	1.5
	Bigtooth	0	0	0.5	1.0
Mortality* (%)	Quaking		7.2	12.5	5.7
	Bigtooth		2.1	0	2.1

*Mortality is measured from June to June of the following year.

It will be interesting to learn how soon gypsy moths will peak again in Osceola County. The unusually high levels of mortality of quaking aspen at Rose Lake (Table 3) are apparently not associated with gypsy moth or any other insect or pathogen. The cause of this mortality will continue to be investigated.

In general, defoliation levels were very low in 1993. The most curious finding of the 1993 survey, however, was that for the first time at any location, bigtooth aspen received more defoliation than quaking aspen in Osceola County (Table 2).

GYPCHECK^{tm}--A FUTURE ALTERNATIVE

Rob Hallett, Program Director
Clare County Gypsy Moth Program

Every since the discovery of the Nucleopolyhedrosis Virus (NPV), a naturally occurring disease in gypsy moth caterpillars, scientists have been attempting to find a way to package this disease to use in the fight against the defoliator. The impetus behind this drive is primarily two-fold: 1) to provide an insecticide that might be more effective than traditionally available chemical and biological pesticides in later instar control and in dense populations of gypsy moth caterpillars, and 2) to provide an environmentally safe insecticide that is also specific only to the gypsy moth, and will not endanger desirable Lepidoptera. Through their efforts, a material called Gypcheck^{tm} has been derived.

Basically two different approaches have been pursued in attempts to commercially produce this pathogen as a pesticide--*in vivo* and *in vitro*.

In vivo production is the process of taking NPV-infected caterpillar cadavers, dehairing and dehydrating them, and grinding them up into powder for spray solution.

In vitro is the process in which the virus is cultured in the laboratory by cell division in sera rather than using live caterpillars for production.

Both processes continue to present many problems in developing mass production methods on a commercial scale. Most significant in the *in vivo* process are the mechanics of rearing larvae and processing them, as it is very labor intensive, as well as expensive. Standard production currently requires approximately 600 larvae for an acre's worth of material at a cost of roughly 3 cents per larvae. That is $18 per acre before costs of sunscreens and stickers are added.

Automated production and application processes are being considered, but have not yet been developed. Synchronized development of larvae have also been a problem, which unless solved, will continue to create labor intensive problems despite any automation developments. An additional production problem has been developing a sprayable formula, processed fine enough to pass through nozzles without destroying the integrity of the material. As a result, test plots using aerial application have been limited, however, progress in this area seems to be occurring.

Problems in *in vitro* production appear to be just as complex. These problems primarily relate to the fact that ideal sera and formulations to fit mass production needs remain elusive. Mass production is hindered by the outdated available inoculation and cell fermentation processes that are currently being used. Compounding this problem, formulas during fermentation require high rates of oxygen. Unfortunately rapid bubbling or agitation creates cell separation and slows down reproduction. Consequently the necessary oxidation process is slowing down production, making it difficult to achieve commercial goals so far.

Other problems regarding potential use of Gypcheck^{tm} include:

- Its high degree of photo-sensitivity.

Current formulations remain viable on foliage for only about three days. Much work is being done on developing new sunscreens to increase persistence. There seems to be much optimism regarding this.

- The virus is slow acting once ingested, generally taking eleven

to sixteen days for mortality to occur.

When applied to early instar populations, this may not be such a limiting factor, and people are expecting fast kill. We have found however, that the public gradually adapts to the slower kill effects of B.t. and will probably accept this as well should it become a usable option.

- Production costs at present remain far too high to make it competitive with available pesticides.

Much of the technology will have to be streamlined before this will change. Some companies have been interested in taking up production. Industry traditionally has been somewhat hesitant to become involved, as competitive factors with other pesticides have been a concern, and they have not been able to project a guaranteed profit. This scenario is apparently changing however, as demands for target integrity rapidly increase. Additionally, virus technology is being utilized on other insects due to the demands of specialized markets, and some of this technology may be able to be adapted.

- Current formulations require a large amount of mixing and handling.

Plans are to develop more concentrated formulations, however, many of the production problems will have to be resolved before this can be addressed.

Efficacy has been very competitive in test plots done to date. Unfortunately, these have all been high dosage applications. Work on low dosage applications has been done on a limited basis. Speculation is optimistic for low dosage application and it is believed that this usage may be effective in retarding rebuilding populations.

I believe it would be safe to assume that we cannot expect Gypcheck[tm] to be an available alternative in our suppression programs in the next few years. However, as public demands for safer, less intrusive pesticide applications increase, and as long as research and industry are willing to pick up the slack, we may be able to look at this innovative material as another tool for suppression within the next decade.

1991-93 Climate and Air Pollution

CLIMATIC AND POLLUTION INFLUENCES ON ECOSYSTEM PROCESSES IN NORTHERN HARDWOOD FORESTS

K. Pregitzer (MTU), J. Witter (U of M), D. Zak (U of M), G. Mroz (MTU), D. Reed (MTU), A. Burton (MTU), N. MacDonald (U of M), and H. Liechty (MTU)

The Michigan Gradient Study, a long-term study of northern hardwood ecosystems, was established in 1987 to examine the effects of acid deposition and climate on forest productivity and ecosystem processes in the Great Lakes region. Intensively monitored study sites were established across a temperature and multiple air pollutant gradient. During 1991 through 1994, we will continue this long-term study on the effects of climate and air pollutants on northern hardwood ecosystems. The objectives for the next three years are as follows: 1) Determine the influence of temporal variation in precipitation and temperature on forest productivity and nutrient cycling; 2) Determine the effects of precipitation, temperature, nitrogen deposition, defoliation, and seed production on stand leaf area and canopy nitrogen content; 3) Determine the influence of soil moisture and temperature on fine root birth, longevity, and mortality; 4) Quantify the effects of soil moisture and temperature on microbial biomass, carbon, nitrogen, and sulfur; 5) Determine if differences exist among sites in kinetics of microbial respiration and sulfur and nitrogen mineralization; 6) Quantify the effects of soil moisture and temperature on soil emissions of carbon dioxide, methane, and nitrous oxide; 7) Quantify soil carbon storage and rates of change across the gradient; 8) Determine the effects of climate on tree growth and survival; 9) Determine the relationship between atmospheric sulfur input and the concentrations of sulfate cations and aluminum in soil solution; and 10) Examine the feasibility of using foliar sulfur:nitrogen ratios as an easily measured bioindicator of sulfate and cation leaching from the soil system. Long-term objectives (4 to 10 years) include: 1) Determine if differences exist among sites in optimal climatic conditions for growth and survival; 2) Determine the effects of temperature on nutrient flux in litterfall and soil solution; 3) Quantify the influence of leaf area index and fine root dynamics on forest productivity; 4) Determine the impacts of insect defoliation on carbon and nutrient fluxes in northern hardwood forests; and 5) Examine high nitrogen deposition sites for increasing trends over time in leaf area index, canopy nitrogen content, nitrogen cycling in litterfall, and forest productivity. For more information, contact Kurt Pregitzer at (906) 487-2396 or John Witter at (313) 764-2249.

EFFECTS OF AN AIR POLLUTION GRADIENT ON NORTHERN HARDWOOD FORESTS IN THE NORTHERN GREAT LAKES REGION: FINAL REPORT

J. Witter (U of M), K. Pregitzer (MTU), G. Mroz (MTU), D. Reed (MTU), D. Karnosky (MTU), M. Jurgenson (MTU), D. Zak (U of M), N. MacDonald (U of M), A. Burton (MTU), and H. Liechty (MTU)

There is great uncertainty about the effects of acidic deposition on forests, and few reliable baseline data exist for most forests of the Great Lakes Region. Data which do exist are not of sufficient quality to assess long-term ecosystem responses to regional air pollution. The effects of pollutants on forest processes, productivity, and vigor are being evaluated and tested by studying northern hardwood forests along the pollution gradient in the Great Lakes Region. This important forest type comprises 5.3 million hectares in the Lake States and 14.7 million hectares nationwide. In Canada, 12% of the total forest volume is maple-dominated northern hardwoods. In terms of overall species mix, the ecosystem utilized in this study is representative of about 80% of the northern hardwood forests in the Great Lakes Region.

The principal objective of this five-year study (1987-1991) was to evaluate the current and possible long-term effects of atmospheric deposition on northern hardwood forests in the Great Lakes Region. The research was designed to address selected hypotheses about how regional air pollution alters nutrient cycling, growth efficiency, carbon allocation, species diversity, seedling recruitment, and genetic diversity of tree species populations. This summary report emphasizes results and interpretations of research data that have been analyzed and summarized by the Michigan Gradient Team as of December 31, 1991.

The study sites were located near Tofte (northeastern Minnesota, Site 1), Alberta (western upper Michigan, Site 2), Pellston (northern lower Michigan, Site 3), Wellston (central lower Michigan, Site 4), and Oceana (southcentral lower Michigan, Site 5). The study sites span 4 degrees of latitude and 6 degrees of longitude, but were very similar in terms of forest stand characteristics. All sites averaged between 29.5 and 31.8 m^2/ha of basal area, with at least 75% of total stand basal area and biomass as sugar maple. Total stand biomass ranged from 212 to 275 Mg/ha, with the two sites at the extremes of the gradient (Sites 1 and 5) having the lowest total biomass. Stand ages were similar, ranging from 73 to 79 years. Soils at all sites developed on morainal landforms, have Udic moisture regimes, and are moderately well to well drained. Soils at all sites were classified in four closely related subgroups within the Spodosol order.

Results from precipitation sampling (1987-1990) confirmed the presence of a pronounced pollutant deposition gradient extending from northern Minnesota to central lower Michigan. Wet deposition of sulfate, nitrate, and hydrogen ions increased with proximity to regional emission sources near the southern end of the gradient. Patterns of deposition correspond well with past patterns of deposition determined from regional monitoring networks.

A relatively simple conceptual model of nutrient pools and fluxes was used to categorize components of the nutrient cycles in northern hardwood forests. Nutrient pools included aboveground woody biomass, foliage, forest floor, soil A and E horizons, and soil B horizons. Fluxes between nutrient pools included wet deposition, dry deposition, litterfall, canopy exchange, retranslocation, wood increment, uptake from soil, and outputs from the system.

To examine possible changes in nutrient cycling due to atmospheric deposition, the inputs to the system (wet and dry deposition) were compared to system outputs (nutrients passing through the B horizon and out of the rooting zone). Outputs were estimated from nutrient concentrations in soil solution sampled below the B horizon. The differences between system inputs and outputs were examined to determine if differences in net ecosystem flux could be related to atmospheric deposition. Foliar nutrient contents, nutrients returned to the soil via litterfall and throughfall, and soil nutrient contents were examined to determine if there had been changes in the internal ecosystem nutrient cycles which might lead to altered overstory productivity.

Our studies indicate that air pollution can alter plant nutrient balances and forest nutrient cycles. Highly significant relationships were found between sulfate deposition and sulfur cycling, sulfur tissue concentrations, and the molar ratios of sulfur:nitrogen in fresh leaves and plant litter. Nitrate deposition also was significantly correlated with nitrogen cycled in plant litter.

Foliar leaching of potassium and calcium was enhanced along the gradient and positively related to concentrations of hydrogen ions in precipitation. No significant differences in canopy exchange rates of magnesium were found among the sites. Canopy exchange rates of

potassium were increased to a greater extent than calcium exchange rates.

Significant positive effects of sulfate deposition on water soluble and adsorbed sulfate and negative effects on sulfate adsorbing potential in upper B horizons suggest that atmospheric sulfate deposition has had a measurable impact on soil sulfate pools and capacities of soils to retain additional atmospheric sulfate. Soil exchangeable cation contents were strongly related to other soil properties such as clay content, organic matter content and cation exchange capacity, but not directly related to pollutant deposition. However, long-term adverse consequences of pollutant deposition on nutrient cation reserves cannot be ruled out.

Soil water chemistry was strongly affected by hydrogen ion and sulfate deposition at both 15 cm and 75 cm sampling depths. Comparison of atmospheric nutrient inputs with nutrient outputs from the B horizons shows that excess sulfate and cations are leaching from the three southern gradient sites. Nitrate outputs exceeded inputs only at Sites 1 and 2 in the north. Nitrate concentrations in the soil solution were correlated with nitrification in the surface soil and with insect defoliation in the overstory canopy. Net losses of sulfate were correlated with atmospheric sulfate deposition. In comparison to weathering rates reported from other eastern Spodosols, potassium and magnesium losses appear to be within the range that can be replaced by weathering. Calcium losses at all sites are in excess of estimated weathering rates, higher than expected losses being directly related to sulfate outputs at the three southern sites.

Based on the analysis of 1988 information, there was no conclusive evidence that stand productivity has been affected by sulfate and nitrate deposition. There were no differences in leaf area index or in increments of net biomass, total basal area, sugar maple biomass, or sugar maple basal area among the five study sites. We are currently linking historical growth records with current on-site climate and growth data to provide an unique perspective on the impact of climate, pollutants, and insect herbivory on growth across all study sites.

The primary objective of our research on fine roots is to build empirical models that integrate the effect of climatic and pollution factors on fine root dynamics. This work is not complete at this time. To date, we have quantified the demographic and life history traits of fine roots on one site. Fine root development appears to be under strong environmental control. We are in the process of integrating soil temperature and moisture information with atmospheric deposition and soil chemistry data so that the effects of various environmental factors on fine root dynamics can be better understood.

There is little information available in the Lake States region that quantifies the interactive effects of pollutants, climate, and pests of northern hardwood forests. Our studies to date have shown that abiotic and biotic factors such as insect defoliators, moisture fluctuations, and temperature fluctuations, if not accounted for, can confound the relationships among nutrient cycling, forest productivity, and air pollution. If these factors are quantified, as we have done, their relative effects on ecosystem processes can be evaluated.

For the past three growing seasons, we have exposed young trees of various species to ozone fumigation and/or nitrogen deposition in open-top chambers in the Lower and Upper Peninsulas of Michigan. Trembling aspen trees are more susceptible to ozone than sugar maple or eastern white pine. Responses of trembling aspen to added ozone included visible foliar injury, reduction in chlorophyll content, increased leaf drop, and above and below ground biomass reductions; no such effects were found on sugar maple or eastern white pine. There is considerable genetic variation in trembling aspen's response to ozone. For example, stem biomass reductions from ozone on trembling aspen varied from 0 to 74% depending on sensitivity of the clone.

A number of other studies are in progress. Results from these studies will be published within the next two years. They include: (1) nitrogen and sulfur mineralization in surface soils, (2) biological and physio-chemical mechanisms of sulfate retention, (3) sulfate adsorption and cation leaching in northern hardwood and oak-hickory forests, and (4) vesicular-arbuscular mycorrhizal development of sugar maple.

The major conclusions to date are:

A. A Pronounced Regional Pollution Gradient Exists Across the Great Lakes Region.

Precipitation sampling confirmed the presence of a pronounced regional pollution deposition gradient extending from northern Minnesota to central lower Michigan. Wet deposition of sulfate, nitrate, and hydrogen ions increased with proximity to regional emission sources near the southern end of the gradient, corresponding to past patterns reported by the National Atmospheric Deposition Program (NADP) regional monitoring network. Natural year-to-year variability in precipitation amounts can substantially alter wet pollutant deposition at specific sites; detection of long-term trends thus depends upon continued monitoring. The NADP monitoring network provides a relatively accurate estimate of wet deposition throughout the Great Lakes Region.

B. Atmospheric Sulfate Deposition Has Altered the Assimilation and

Cycling of Sulfur in Northern Hardwood Forests.

The amount of sulfur returned in litter and the concentration of sulfur in live foliage and litter were linearly related with wet deposition of sulfate in both precipitation and throughfall. The molar ratio of sulfur:nitrogen in litter and live foliage increased across the gradient and the pattern was consistent for 1987, 1988, 1989, and 1990 regardless of the method of partitioning litter flux. Because of the interdependent nature of sulfur and nitrogen metabolism, the increase in sulfur cycling at sites with higher sulfate deposition is almost certainly not due to increases in foliage production, climatic conditions, or the deposition of atmospheric nitrogen. It is due to the atmospheric deposition of sulfur. Altered nutrient ratios in plant tissue demonstrate that nutrient imbalances can be induced by pollutant deposition over wide geographic areas.

C. Atmospheric Nitrate Deposition May Have Altered Nitrogen Cycling in Northern Hardwood Forests.

There was a significant linear relationship between the atmospheric deposition of nitrate and nitrogen returned to the soil as litter. The existing records of litter flux (four years) and ambient soil temperature and moisture (two years) are simply too short to determine if nitrogen cycling is related to pollution or the underlying change of climate across the gradient. The long-term implications of anthropogenic changes in nitrogen cycling have very important ecological ramifications within plant communities and for the biosphere, because nitrogen is a limiting element in many forests, nitrate is a ground water contaminant, and nitrous oxide is an important greenhouse gas.

D. Atmospheric Deposition Has Altered the Exchange of Nutrients in Forest Canopies.

Foliar leaching of potassium and calcium were positively related to concentrations of hydrogen ions in precipitation. Canopy exchange rates of potassium appeared to be more sensitive to changes in precipitation acidity than were calcium exchange rates. Forest canopies appear to assimilate nitrogen at all levels of deposition. Accelerated rates of foliar cation leaching related to acidic deposition have ramifications for long-term forest productivity and maintenance of ecosystem nutrient reserves.

E. Atmospheric Deposition of Hydrogen Ions and Sulfate has Increased Cation Leaching from Soils.

Soil solution concentrations of sulfate, calcium, magnesium, and potassium were positively correlated with both hydrogen ion and sulfate deposition. Losses of sulfate were highly correlated with atmospheric sulfur deposition. Sulfate increased in dominance as a mobile anion in the soil solution at the southern sites. As a percentage of total inorganic anions in soil solution on an equivalent basis, sulfate increased from <37% at Sites 1, 2, and 3 to 51% at Site 4 and 59% at Site 5. Soil solution sulfate in excess of background levels is implicated in increased cation leaching of 8 to 34% at the three southern sites. In the long term, it is possible that cation leaching associated with acidic deposition will result in decreased soil fertility, with losses exceeding estimated weathering rates. The gradient approach provides reasonable and regional interpretable rates of cation leaching due to atmospheric deposition.

F. Additional Information is Needed to Determine if There is A Relationship Between Acidic Precipitation and Forest Productivity.

Based on results to date, there is no conclusive evidence that deposition of sulfate or nitrate is altering biomass or basal area increments, mortality rates, or growth efficiency on the study sites, either directly or indirectly. Information extending over a longer time period is needed to fully assess the impacts of sulfate and nitrate additions on forest productivity.

G. Biotic and Abiotic Factors Can Confound Relationships Among Nutrient Cycling, Productivity, and Air Pollution.

Insect defoliation directly altered the flux rates of nutrients in throughfall, litter, and soil solution at two of the five study sites during 1988. Moisture and temperature fluctuations have the potential to do the same. These factors may synergistically enhance or mitigate air pollution impacts on forest health. Therefore, assessment of forest health requires measurement of a variety of environmental factors and must occur over extended measurement periods.

H. Gradient Studies Provide Useful Results.

Although not a controlled experiment in the traditional sense, this research has clearly demonstrated that certain aspects of the nutrient cycles of northern hardwood forests have been altered by acidic precipitation. Therefore, the original policy questions have been answered in a regional context and at a scale that enables reasonable policy analysis. Climate does vary across the pollution gradient, and makes the interpretation of processes intimately linked to the carbon cycle, such as nutrient cycling and forest productivity, more difficult to interpret; however, covarying climatic and pollution gradients are a reflection of real-world conditions, and not an artifact of study design. The climatic gradient may in fact be a major asset, because this pollution/

climatic gradient spans those latitudes where climate is predicted to change most dramatically in the next 100 years. Carefully performed gradient analysis is a useful approach to understand forest ecosystem processes and their relationships to natural and anthropogenic factors. Carefully established study sites and documented research along pollution and climatic gradients will be extremely valuable in the long term, and where they exist, such studies must be maintained.

For more information, contact John Witter (313) 764-2249, Kurt Pregitzer (906) 487-2396, or Glenn Mroz (906) 487-2496.

1991-93 Forest Health Conditions: Special Projects

FOREST INVENTORY AND ANALYSIS: 1991-1992

DAMAGE CODE STANDARDIZATION PROJECT

Robert L. Heyd (MDNR)

Insects and diseases kill approximately 150 million cubic feet of timber in Michigan annually. This loss represents slightly less than one-half of the total annual harvest. In addition, damage to trees from insects and diseases reduces timber growth by an estimated 300 million cubic feet each year. Michigan's Forest Health Program continually seeks new understandings of how losses impact the quality of our forest resource. Once losses are identified, we seek cost-effective options to improve renewable resource uses of our commercial forest land. One source of information is the U.S. Forest Service, Forest Inventory and Analysis (FIA) Program.

Federal legislation mandates that periodic inventories and assessments be made of the nation's forest resources. The U.S. Forest Service has the responsibility for meeting this mandate. The North Central Forest Experiment Station, Forest Inventory and Analysis, St. Paul, Minnesota, is responsible for the periodic inventory of 11 states including Michigan.

The Forest Service remeasures an established network of permanent inventory plots every 10 years. Changes that take place between surveys reflect land use, growth and removals. One aspect of this monitoring is an assessment of the causes of tree mortality and growth loss (insects, diseases, storm damage, drought, etc.). The Forest Service and most the 11 states in the North Central Region thoroughly reviewed past inventory coding used for loss assessment. The fruit of this labor was the initiation of a new Damage Code Standardization which will better serve the needs of state and federal forest health programs. It better defines losses, and improves the combining and assessment of data from all 11 states. This information is important for forest health program development. As already stated, we need to understand where and why losses are occurring. Such information is used to develop improved management strategies and define research needs.

U.S. Forest Service stand examiners for Michigan's Forest Inventory and Analysis Survey are trained in the use the new Damage Codes by members of Michigan's Forest Health Program. A major benefit of state sponsored training is insuring the awareness of problems unique to Michigan.

Editors Note: FIA data has been collected and compiled for 1993-94. An article presenting major findings will appear in the *1994 Michigan Forest Health Report.*

DETERMINATION AND QUANTIFICATION OF SUGAR MAPLE DECLINE IN MICHIGAN:

NORTH AMERICAN MAPLE PROJECT (NAMP) 1988-1992

C. Randall (MSU), J. Witter (U of M), R. Heyd (MDNR)

During the late 1970's and early 1980's foresters and sugarbush managers became concerned with sugar maple decline. The North American Sugar Maple Decline Project (NAMP) was developed in 1987 between Canada and the United States. The project established 165 sugar maple plot clusters (5 plots per cluster) for observation in 1988. As of 1993, there are 233 clusters. They are distributed throughout North America from Wisconsin and Ontario to Massachusetts and Nova Scotia. Half of the plot clusters in each state or province are located in sugarbushes and the other half are in unmanaged sugar maple forests. There are eighteen plot clusters in Michigan, ten in southeastern Michigan, and eight in the Upper Peninsula. Data have been collected in southeastern Michigan plots since 1988 and Upper Peninsula plots were added in 1991. Sugar maple crowns are evaluated annually for branch dieback, foliage transparency, discoloration, dwarfed foliage and insect defoliation.

The information on NAMP and the data summaries for this article are taken from D. Allen, C. Barnett, I. Millers and D. Lachance, 1992, *Canadian Journal of Forest Research,* (Vol. 22, No. 11, pages 1776-1784), and from an annual report submitted by R. Cymbala and D. Allen, April 1993, of the State University of New York, entitled *Temporal Change in Sugar Maple Crown Conditions from 1988-1992: North American Maple Project.*

The two main parameters used to determine the health of sugar maples included in the NAMP survey are average crown dieback and crown transparency for live, dominant/ codominant sugar maples. Transparency (or the amount of light passing through a tree's foliage) and dieback (recorded as a percentage crown dieback class) are rated for each tree and averaged for the stand. Average *cluster* dieback and transparency ratings have been determined for the entire North American project area and for Michigan. The average ratings for sugarbush and non-sugarbush stands from 1988 to 1992 are summarized in Table 1.

Overall, sugar maple conditions have improved in Michigan and in North America from 1988 to 1992. There has been a general four-year decrease in dieback since 1988, but these decreases are not statistically significant when comparisons are made on an annual basis. Statistically significant differences are found, however, in both Michigan and North America when 1988 is compared with 1992. In North America the difference in average dieback between 1988 and 1992 was 2 percent, and in Michigan the difference was 5.3 percent. Cymbala and Allen (1993) point out that the project-wide decrease of 2 percent is not biologically important given the width of the rating classes. However, they also state that "the statistical significance of the 1988 to 1992 comparison suggests that the cumulative effect of small annual decreases may have biological importance over time."

The data in Table 1 also illustrate that sugarbushes have slightly higher dieback ratings than non-sugarbush stands in both Michigan and the entire project area. However, the differences between management categories are not statistically significant when compared on an annual basis.

There are few statistically significant comparisons for average cluster transparency ratings in Michigan and project-wide either from within or between management categories (sugarbush and non-sugarbush). A statistically significant decrease in average cluster transparency of 6

Table 1. Average Cluster Dieback and Transparency Ratings for Sugar Maples in Sugarbushes and Undisturbed Stands: North America and Michigan (includes eight plots clusters established in 1991).

	North America						Michigan					
	Sugarbush			Non-Sugarbush			Sugarbush			Non-Sugarbush		
Year	(%)	±S.E	*n*	(%)	±S.E.	*n*	(%)	±S.E.	*n*	(%)	±S.E	*n*
AVERAGE CLUSTER DIEBACK												
1988	8.7	(±0.4)	84	7.1	(±0.3)	81	9.7	(±1.8)	5	7.5	(±0.3)	5
1989	7.5	(±0.3)	84	5.9	(±0.2)	81	9.9	(±1.9)	5	9.0	(±1.1)	5
1990	7.2	(±0.3)	84	6.2	(±0.2)	81	6.0	(±0.3)	5	5.0	(±0.0)	5
1991	6.5	(±0.3)	84	5.5	(±0.3)	81	5.2	(±1.1)	9	2.3	(±0.6)	9
1992	6.6	(±0.4)	85	5.2	(±0.3)	80	5.3	(±1.0)	9	3.2	(±0.5)	9
AVERAGE CLUSTER TRANSPARENCY												
1988	17.7	(±0.7)	84	16.1	(±0.7)	81	15.9	(±1.7)	5	13.7	(±2.5)	5
1989	20.1	(±0.5)	84	18.1	(±0.5)	81	15.6	(±1.3)	5	14.3	(±0.8)	5
1990	14.7	(±0.6)	84	13.7	(±0.5)	81	9.4	(±0.8)	5	8.4	(±0.9)	5
1991	12.0	(±0.3)	84	11.6	(±0.4)	81	9.1	(±1.0)	9	8.3	(±1.0)	9
1992	13.7	(±0.4)	85	13.3	(±0.4)	80	10.7	(±1.6)	9	10.6	(±1.8)	9

percent was observed in Michigan between 1989-1990. The higher average cluster transparency ratings observed in 1989 in both North America and Michigan can be attributed to the severe drought that occurred in Michigan and Wisconsin, and to an outbreak of pear thrips in Massachusetts and Vermont.

The data acquired from NAMP cooperators to date do not indicate any widespread decline or mortality of sugar maple forests. Attempts to determine if atmospheric depositions (e.g. acid rain as measured by sulfate wet deposition) have not yielded significant results. There were no significant differences in the health of sugar maple stands in either Michigan or North America related to high-, moderate-, or low-sulfate wet deposition zones (Allen, Barnett, Millers, and Lachance, 1992). The problems observed in individual sugar maples and some localized stands have largely been attributed to insects, pathogens, mismanagement, weather conditions (primarily drought) and/or poor sites for sugar maples.

Overall it appears that sugar maple crown conditions have improved between 1988 and 1992. Six more plot clusters were added in 1993 and further updates in NAMP are expected for the 1994 field season. Information and brochures on NAMP can be obtained by contacting Robert Cymbala or Doug Allen at the College of Environmental Sciences and Forestry, State University of New York, 133 Illick Hall, 1 Forestry Drive, Syracuse, NY 13210-2778, phone (315) 470-6886.

RESEARCH SUMMARIES: FOREST ENTOMOLOGY PROGRAM MICHIGAN STATE UNIVERSITY

Deborah McCullough (MSU)

Endangered Karner Blue Butterfly

Cathy Papp and Deb McCullough (MSU) and Robert Haack and Leah Bauer (USDA Forest Service)

We began studying critical habitat requirements of the Karner Blue butterfly *(Lycaeides melissa samuelis)*, a federally listed endangered species in 1993. In Michigan, this small skipper occurs in oak savannah ecosystems in the southwestern and west-central Lower Peninsula. Field studies are in progress to determine the relative importance of lupine (the larval foodplant), nectar plants, canopy cover and other factors. Preliminary data indicate that abundance, distribution and phenology of lupine, and canopy cover (up to 40%) are associated with high Karner Blue populations. Ant-tending of larvae also seems to be very common and may protect feeding larvae from predators. In addition, we have determined that Karner Blue larvae may overlap spatially and temporally with gypsy moth populations in Michigan oak savannah forests. Currently we are working with USDA Forest Service researchers to determine if Karner Blue larvae are susceptible to B.t., the microbial insecticide commonly used in gypsy moth suppression programs.

Jack Pine Budworm

Deb McCullough (MSU), Larry Marshall (Canadian Forest Service), and Lyle Buss (MSU)

We have been intensively studying impacts of jack pine budworm *(Choristoneura pinus pinus)* in four management compartments of the Hiawatha National Forest since 1992. Data on defoliation topkill and mortality resulting from the recent jack pine budworm outbreak have been collected for over 100 stands. Budworm data will be integrated with current inventory and Geographic Information Systems (GIS) data for each stand. This information will be used to identify site and stand traits most closely associated with budworm damage. Hazard rating systems that identify relative risk of budworm damage will be tested, refined and incorporated into the Jack Pine Budworm Decision Support System, currently under development in Canada.

Native Forest Insect Biodiversity

Tim Work and Deb McCullough (MSU)

We began a study in 1993 to collect baseline data on the abundance, diversity and community structure of native forest insects in two specific ecosystems in the Manistee National Forest. Study sites were located in northern hardwood ecosystems and red oak ecosystems, as defined by the Ecological Classification System in use on the Manistee Forest. Half of the sites in each ecosystem had high gypsy moth *(Lymantria dispar)* populations in 1993; the other sites had not yet experienced gypsy moth infestation. Insects were collected monthly during the summer from ground, shrub, and canopy strata, using a variety of sampling

methods. All insects will be identified minimally to family and assigned to feeding guilds. Lepidoptera, the group most likely to be impacted by gypsy moth, will be identified to species level. Preliminary data collected so far suggest that insect communities differ between the two ecosystems and that some guilds of native insects may be negatively affected during peak gypsy moth defoliation. Information acquired in this study is needed before impacts of disturbance or management activities can be evaluated in specific ecosystems.

Gypsy Moth Biological Control

Lyle Buss, Deb McCullough and Carl Ramm (MSU)

A study was started in 1993 in Kellogg Experiment Forest and Lux Arbor Reserve, in Kalamazoo County. The first objective of the study is to compare three different methods of predicting gypsy moth populations and defoliation. Counts of male moths in pheromone traps, egg mass counts in fixed radius plots and egg mass counts along 100 tree transects will be compared and associated with gypsy moth defoliation in selected compartments. A second objective is to evaluate the establishment and dispersal of two introduced biological control agents. *Entomophaga maimaiga*, a fungal pathogen, and *Cotesia melanoscelus* were introduced into specific compartments in 1994, with the cooperation of the Michigan Department of Natural Resources (MDNR). Weekly surveys will be conducted to determine if either of the natural enemies become established, and if so, how far they disperse. The third objective of the study is to quantitatively evaluate costs and benefits of the population sampling methods and the two biocontrol agents.

Calasoma Release: In addition Tom Ellis, Fred Stehr and Deb McCullough (MSU) recently cooperated with the MDNR in a release of *Calasoma syncophanta* in the northern Lower Peninsula. This brightly colored ground beetle is an aggressive predator of gypsy moth larvae and pupae. Follow-up surveys will be conducted to evaluate its establishment and effectiveness.

Christmas Tree IPM

Eileen Eliason, Deb McCullough and Tom Ellis (MSU)

Several varieties of Scotch pine are currently being tested at Kellogg Forest and on a plantation in Greenville to determine if they exhibit resistance to selected insect pests. Caging studies will be used to determine if survival and fecundity of European pine sawfly *(Neodiprion sertifer)*, Zimmerman pine moth *(Dioryctria zimmermani)*, and pine needle scale *(Chionaspis pinifoliae)* differ among the Scotch pine varieties. In addition, observations are made periodically to determine natural rates of insect infestation and damage. These results will be integrated with related studies in progress to identify and propagate superior varieties of Scotch pine for Michigan Christmas tree production.

Pine shoot beetle *(Tomicus piniperda)*: State and federal regulations restricting movement of pine Christmas trees, forest products, and nursery stock have caused headaches for growers and forest products companies in Michigan since this pest was detected in 1992. Studies were started in 1993 to develop integrated pest management (IPM) recommendations to allow growers to ship pine products out of the regulated area. Data was also collected on distribution of damage within the canopy during maturation feeding. Currently we are evaluating cultural, biorational, and insecticide products to determine effective ways of managing pine shoot beetle populations. Full-scale education programs have been underway since 1992 to inform growers about the pest and management options.

Other insect pests: We are also testing pheromone lures for Zimmerman pine moth and eastern pine shoot borer *(Eucosma gloriola)*, two insects that are common pests in Christmas tree plantations. These studies are being conducted in cooperation with the USDA Forest Service and the Canadian Forest Service. Our goals are to assist in development of an effective pheromone trap to detect and monitor phenological development of these pests. We are also testing effectiveness of diflubenzuron for Zimmerman pine moth control to determine how well this product compares to conventional insecticides.

Gypsy Moth Education

Cora Gorsuch, Tom Ellis and Deb McCullough (MSU)

The Michigan Gypsy Moth Education Program continues to flourish. Recent activities have included development of information on gypsy moth natural enemies, a gypsy moth information packet for state legislators and co-sponsoring an annual training session for county suppression program coordinators (with the Michigan Department of Agriculture). We have also initiated several projects to help Michigan science teachers use gypsy moth in classroom activities. Ongoing education projects include studies that link gypsy moth management with pesticide and water quality issues in

the western Lower Peninsula. Planning is underway to develop a high school curriculum that examines impacts of gypsy moth, zebra mussel, and other exotic pests on native species.

McCullough and Robert Neumann (MSU) are also directing an information and education program in the Upper Peninsula to support the Gypsy Moth Slow-the-Spread (STS) program. Goals of the information/ education program are to reduce the risk of inadvertent transport of egg masses or other life stages across the STS zone, and to enlist cooperation from property owners during pheromone trapping. Various brochures, fact sheets, newspaper, radio and television news releases and a STS video have been produced to raise awareness about gypsy moth and the STS project.

LARGER PINE SHOOT BEETLE

Robert A. Haack and Robert K. Lawrence

USDA Forest Service, North Central Forest Experiment Station, East Lansing, Michigan

The larger pine shoot beetle (*Tomicus piniperda*), is one of the most important bark beetle pests of pine in Europe and Asia. In July 1992, established populations of this beetle were discovered near Cleveland, Ohio. As of December 1993, surveys by federal, state and provincial officials revealed that the pine shoot beetle was present in 92 counties in 6 Great Lakes states (Illinois, Indiana, Michigan, Ohio, Pennsylvania, New York), and 7 counties in the province of Ontario (Source: National Agricultural Pest Information Service, USDA Animal & Plant Health Inspection Service, Hyattsville, MD; and Agriculture Canada, Plant Protection Division, Ottawa, Ontario). In Michigan, the beetle had been detected in 30 counties in the southern half of the Lower Peninsula as of December 1993.

The beetle's wide distribution in North America indicates that this pest has become firmly established and has probably been present in the Great Lakes region for several years. Due to the impact of the pine shoot beetle in Eurasian forests, it represents a potentially serious threat to North American pine forests. A federal quarantine went into effect in November 1992 restricting the movement of pine Christmas trees, nursery stock, boughs, and logs with bark attached in areas known to have populations of the beetle.

The pine shoot beetle produces one generation per year. Adults overwinter in the bark at the base of pine trees. They emerge in early spring, generally after the first two or three consecutive days of temperatures greater than 50°F, and fly to breeding sites in pine logs, slash, stumps, and recently dead trees, where they construct galleries and lay eggs beneath the bark. Larvae grow and tunnel under the bark until they emerge as new adults in May or June. They then fly to the upper crowns of healthy pines, tunneling and feeding inside shoots until the first frosts of autumn occur.

Several federal, state and university researchers in the U.S. are studying the biology and ecology of the pine shoot beetle and techniques to manage infestations. In Michigan, we have been investigating: 1) the life history and seasonal development of the pine shoot beetle; 2) susceptibility of North American conifers; 3) ecological relationships between the pine shoot beetle and natural enemies, fungi, and other pest species; 4) survey tools; and 5) management tactics. Various tactics for managing pine shoot beetle infestations are also being studied by Dr. Deborah McCullough of Michigan State University.

Research results thus far indicate that the pine shoot beetle is well adapted to life within its current range in the Great Lakes region. In 1993, spring flight activity of adults began in late March and early April, 4 to 5 weeks before first flight of native pine bark beetles (*Dendroctonus valens*, *Ips grandicollis*, *Ips pini*, and *Orthtomicus caelatus*) and their principal predators (clerid, histerid, and tenebrionid beetles). Thus, pine shoot beetles were able to utilize breeding sites for a few weeks in the absence of interspecific competition or predation.

Three eastern pine species (eastern white, jack, and red) and three

western pine species (limber, ponderosa, and western white) were tested in 1993 for suitability as hosts for the pine shoot beetle. Scotch pine, the native host of this beetle, was used as a control in all tests. Pine shoot beetles were able to breed in logs and feed in healthy shoots of all pine species tested, although the two white pine species appear to be less susceptible than the others.

Overwintering behavior of the pine shoot beetle was examined in Scotch pine Christmas trees. In 1992 and 1993, beetles departed shoots in late October and November and moved to overwintering sites on the lower trunks of the trees within 20 cm of the soil. In one experiment, Scotch pine Christmas trees containing overwintering pine shoot beetles were cut in December 1993, brought indoors, and placed in watered tree stands. After one month, pine shoot beetle galleries, eggs and larvae were found in the trunks of several of the trees, thus indicating that beetles transported in Christmas trees have the potential for survival and reproduction.

Lindgren funnel traps baited with alpha-pinene lures proved to be effective tools for monitoring spring flight activity. Although the greatest numbers of beetles were caught during the beginning of the flight period, beetles continued to be collected into June. The absence of beetles in traps after this time adds credibility to the concept of a safe "harvesting window" between July and September --i.e., that pines can be cut and the logs removed from the forest during the time that beetles are feeding in the shoots with little risk of transporting beetles.

Pine logs can also be used for trapping pine shoot beetles. One-meter long logs from Scotch pine and other rough-barked pines were heavily attacked by the pine shoot beetle in our studies. Such logs could be effectively used as traps in beetle detection surveys, or as a means to reduce beetle populations in pine plantations, if placed in plantations before spring flight and then destroyed in late April or May before parent and progeny beetles emerge from the logs.

The most effective tactic currently available to a grower for managing a pine shoot beetle infestation is to maintain a clean operation and limit the number of potential breeding sites present. Freshly cut (less than 8 months) pine stumps, logs, slash, and dead trees should be destroyed by chipping or burning prior to beetle flight activity in March or April.

YELLOWHEADED SPRUCE SAWFLY

Robert K. Lawrence and Robert A. Haack

USDA Forest Service, North Central Forest Experiment Station, East Lansing, Michigan

An outbreak of the yellowheaded spruce sawfly, *Pikonema alaskensis*, has occurred during the past two years in a black spruce provenance plantation at the W.K. Kellogg Experimental Forest (Kalamazoo County, Michigan). Defoliation first reached noticeable levels in 1992 and increased dramatically in the following year. More than half of the trees were heavily defoliated in 1993; many were completely defoliated. U.S. Forest Service entomologists measured sawfly impact in that genetics plantation in 1993 and will continue to assess black spruce defoliation, mortality and recovery.

THE KIRTLAND'S WARBLER IN 1993

Jerry Weinrich (MDNR)

INTRODUCTION

The first Kirtland's warbler (*Dendroica kirtlandii*) census was organized by Harold Mayfield in 1951. Mayfield's census results were published in 1953. The census was to be repeated every 10 years, and the second census in 1961 recorded a total similar to that of 1951. The 1971 census, however, revealed a precipitous drop in the population--a decline of approximately 60 percent from the 1961 count. In order to monitor the population more closely, censuses have been conducted every year since 1971.

Mayfield coordinated the censuses through 1975 and the Wildlife Division of the Michigan Department of Natural Resources has assumed this responsibility since. From 1976 through 1985, coordination was through the Wildlife Division's Surveys and Statistics Section. In 1986 responsibility for the census was delegated to the Houghton Lake Wildlife Research Station.

METHODS

From mid-May through early June, cooperators from the Michigan Department of Natural Resources, Michigan Department of Military Affairs, U.S. Forest Service, U.S. Fish and Wildlife Service, and private volunteers check areas of likely habitat for the presence of singing male Kirtland's warblers. During the actual census period (June 6 through 15 in 1993), all newly-occupied areas, areas occupied the previous year, and most areas with likely habitat are searched for singing males. The time period for the actual census is intentionally short so that the possibility of double-counting males moving from one area to another is minimized.

Since nearly all areas occupied by Kirtland's warblers are closed to public entry from May 1 to at least August 15, census personal are required to have a permit(s) from the Department of Natural Resources (state lands) and/or the U.S. Forest Service (national forest lands). Nesting areas are closed to prevent disturbance to the warbler and its habitat. Accordingly, census personnel take precautions to minimize any disturbance they might cause. Small areas with only a few singing males are checked from the periphery or from roads to prevent walking through nesting habitat. For large areas of habitat, census personnel walk simultaneous transect lines with the minimum number of people necessary to assure hearing all singing males. Transects are usually only run once and roads and areas of "non-habitat" are used where possible. Male Kirtland's are loud and (usually) persistent singers, and most observers can hear their songs for at least 0.2 miles; those with exceptional hearing can hear the song for 0.5 miles under good conditions. The location of all singing males is recorded on sketch maps and these plus records for all areas checked are used to tabulate final census results.

RESULTS AND DISCUSSION

The 1993 census found 485 singing male Kirtland's warblers in Michigan (Table 1). This represents a significant increase of 22 percent from the 1992 count of 397, and a near three-fold increase from 1987 when the count was only 167. The 1993 count is the highest of the 23 censuses conducted since annual counts were begun in 1971. Because of its large area of prime habitat, the New Mack Lake Burn (Oscoda County) again had the highest number of singing males, as it has since 1987. The 1993 census found 344 males in Oscoda County, 295 of which were in the New Mack Lake Burn. The Oscoda County total represents 71 percent of the total. The count for Ogemaw County increased by nearly 60 percent, from 51 in 1992 to 81 in

Table 1. Counts of Singing Male Kirtland's Warblers by County*

Location Michigan Counties	1951	1961	1971	1981	1985	1986	1987	1988	1989	1990	1991	1992	1993
Alcona	4				1	1	1	6	6	4	7	8	11
Crawford	142	52	101	72	80	84	66	63	55	59	65	52	34
Iosco	74	30	1	3	7	3		3	8	5		4	3
Kalkaska	28	32		32	21	16	10	11	7	5	7	4	4
Montmorency	43	61	1										
Ogemaw		114	47	50	22	17	13	15	12	17	35	51	81
Oscoda	103	152	48	67	80	81	68	100	115	166	226	274	344
Otsego		14	3										3
Presque Isle	34	34											
Roscommon	4	13		8	5	8	9	9	9	9	7	4	4
Schoolcraft													1
Michigan Total	432	502	201	232	216	210	167	207	212	265	347	397	485
Wisconsin								8	2	1	1	1	
Ontario					1					1			
North American Total	432	502	201	232	217	210	167	215	214	267	348	398	485

*Certain inventory years prior to 1985 are omitted for abbreviation purposes.

1993, while the number of singing males in Crawford County declined by 35 percent, from 52 in 1992 to 34 in 1993. Other Lower Peninsula counties where warblers were found were: Alcona (11), Kalkaska (4), Roscommon (4), Iosco (3), and Otsego (3). The 3 singing males found in Otsego County this year are the first documented for this county since 1971.

Areas of likely habitat in several adjacent states and provinces have been checked for Kirtland's warblers since 1977. Since then, warblers have been found in Ontario, Quebec, and Wisconsin. No Kirtland's warblers were found outside Michigan in 1993. Again this year, a large number of young jack pine stands in the eastern Upper Peninsula were checked for singing male Kirtland's warblers. One apparently unmated male was found this year near Steuben in Schoolcraft County.

Distribution of warblers in 1993 was similar to that of 1990-92 in that virtually all were located in areas of young or middle-age habitat. The largest area of young habitat, the New Mack Lake Burn, continued to attract more singing males. The count for this area increased by 18 percent from 250 in 1992 to 295 in 1993, and this concentration of birds represents 61 percent of the total population, a proportion similar to that since 1990. The Bald Hill Burn in Crawford County had 20 singing males in 1993 compared to 34 in 1992. More than offsetting this decline, The Big Creek Management Area in Oscoda County showed an increase from 15 males in 1992 to 34 in 1993. Similarly, the Perry Holt East, Ogemaw KWMA, and Hippie Burn areas in Ogemaw County all showed substantial increases in the number of singing males.

Encouragingly, the 1993 count found 166 singing males (34 percent of the total) in areas specifically planted for warbler habitat. The challenge remains to ensure that enough quality habitat will be available in 10 to 15 years to at least maintain the increased population resulting from the large acreage of prime nesting habitat available now.

The 1993 Michigan census involved at least 74 individuals and it was a cooperative effort of the Michigan Department of Natural Resources, U.S. Forest Service, U.S. Fish and Wildlife Service, Michigan Department of Military Affairs and a number of independent volunteers.

In Memoriam

Two pioneers in the study and recovery of the Kirtland's warbler, Dr. Lawrence Walkinshaw and Dr. Nicholas Cuthbert, passed away in 1993. Their enthusiasm insight and encouragement will be sorely missed. It was indeed a pleasure to have been able to work with these two outstanding scientists and gentlemen.

Excerpted from Wildlife Division Report #3201.

REFORESTATION

Bill Botti (MDNR)

Between the Fall of 1991 and Spring 1993 the Michigan Department of Natural Resources planted or seeded over 10,000 acres of state forest land. This included considerable acreage planted by the Wildlife Division for Kirtland's warbler habitat and for deer habitat. The breakdown of reforestation efforts by location and tree species are summarized in the following table.

Table 1. Reforestation Accomplishments for Fall 1991 through Spring 1993.

Tree Species	Number of Acres Planted by Location (State Forest) Copper Country	Escanaba	Lake Superior	Mackinaw	Au Sable	Pere Marquette	KWP*	TOTAL ACRES
FALL 1991								
PLANTED ACRES								
Jack Pine				45				45
BROADCAST OR MACHINE SEEDED								
Jack Pine					111	50		161
SPRING 1992								
PLANTED ACRES								
Jack Pine	28	336	617	334	666		1,500	3,481
Red Pine		146	321	266	188	513		1,434
Red Oak	11	50						61
Tamarack	9	1						10
White Cedar			18					18
FALL 1992								
PLANTED ACRES								
Jack Pine				204				204
BROADCAST OR MACHINE SEEDED								
Jack Pine					105			105
SPRING 1993								
PLANTED ACRES								
Jack Pine	11	462		320	919	49	1,500	3,261
Red Pine	46	109	147	6	524	220		1,052
Hybrid Aspen						20		20
White Pine		9	66					75
White Cedar			0.5					0.5
BROADCAST OR MACHINE SEEDED								
Jack Pine				75	145	69		289
White Cedar			115					115
Red Oak						4		4
TOTAL ACRES	105	1,113	1,284.5	1,250	2,658	925	3,000	10,335.5

*Kirtland's Warbler Program